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Petrological and maturation characteristics of organic matter from the middle proterozoic McArthur Basin, Australia

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**PETROLOGICAL AND MATURATION CHARACTERISTICS OF
ORGANIC MATTER FROM THE MIDDLE PROTEROZOIC McARTHUR
BASIN, AUSTRALIA.**

A thesis submitted in fulfilment of the requirements
for the award of the degree of

DOCTOR OF PHILOSOPHY

from

THE UNIVERSITY OF WOLLONGONG

by

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(B.Sc.(Hons), University of Melbourne, 1967)

Department of Geology

1989

Except where otherwise acknowledged in the text, the contents of this thesis are the result of original research by the author. The work has not been previously submitted for a degree to any other university or similar institution.

I. H. Crick

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ABSTRACT

Organic matter in middle Proterozoic sedimentary rocks of the McArthur Basin occurs predominately within fine-grained clastic sediments and is made up of the petrographically discernable entities, lamalginite, bitumen, thucholite and oncalginite. With increasing maturation, fluorescence in lamalginite diminishes from bright yellow to dull brownish-orange and eventually ceases. Disaggregation of nonfluorescent lamalginite may have led to the formation of some types of bitumen. The lamalginite probably formed from a variety of micro-organisms but few are preserved in the lamalginite.

Reflectances of discrete maceral types generally show systematic increases with increasing depth, but discontinuities occur where fluorescent lamalginite gives way to nonfluorescent lamalginite and bitumen. The relationships of reflectance and Tmax indices to the oil window, and of observed reflectances to calculated vitrinite reflectances, derived from methylphenanthrene indices, are established.

Maturation levels in the McArthur Basin range from marginally mature to overmature. Contact metamorphism in the Roper Group and hydrothermal activity, associated with base metal mineralisation in places, in the McArthur Group, have locally increased maturation levels. Maturation levels in the Roper Group that are unaffected by contact metamorphism, display a pattern consistent with the concept that the Roper Group formed during the sag phase of the basin's development and that there has been subsequently a relatively uniform geological history. Maturation levels in the McArthur Group that are

unaffected by hydrothermal activity, show a different pattern resulting from variable subsidence rates and geothermal gradients during the final phase of extension in the basin which preceded the sag phase.

Comparisons between modelled vitrinite reflectances and observed reflectances, recalculated to equivalent vitrinite reflectances, suggest that the Roper Group was up to about 1000 m thicker than its observed maximum thickness and that sedimentary cover overlying the McArthur Group was less than 2000 m in places.

Hydrocarbon generation occurred from organic-rich units within the Roper and McArthur Groups, particularly from the Velkerri and Barney Creek Formations which contain up to 7% total organic carbon. Oil generation from these formations commenced before 1000 Ma but low rates of oil generation may have continued, at low temperatures, for a considerable period of time extending well into the Phanerozoic.

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CHAPTER 1

INTRODUCTION AND AIMS

Australian crude oil will become an increasingly rare commodity with production probably falling to about 25% of total requirement by the year 2000 after having been at 100% in 1985 (McEvoy, 1987). Exploration for oil in Australia and worldwide has concentrated on Phanerozoic basins with only minor attention being given to Precambrian Basins (Murray et al., 1980; Hatch and Morey, 1985) yet carbonaceous rocks are known from the Archaean (McKirdy, 1974; Hunt, 1979). The Russians discovered in 1962 commercial quantities of oil and gas in the giant Markovo field near Irkutsk in Cambrian and Proterozoic formations (Vassoevich, 1971, quoted from Hunt, 1979) and since then further commercial quantities of hydrocarbons have been discovered in Late Proterozoic sediments in Siberia (Meyerhoff, 1980) and Oman (Al-Marjeb and Nash, 1986). In Australia, a significant but non-commercial gas flow from Late Proterozoic sediments in Exoil's wildcat well, Ooraminna 1, in the Amadeus Basin (Siller et al., 1963) was the first indication that commercial quantities of hydrocarbons might be discovered in the Australian Precambrian. Since then, an economic, but as yet undeveloped gas field, Dingo, was discovered in 1981 within Late Proterozoic sediments of the Amadeus Basin (Gorter et al., 1982).

Precambrian rocks are exposed over large areas in Australia but in many places have had thermal and tectonic histories that preclude any possibility of finding hydrocarbons. However, in the middle Proterozoic McArthur Basin, which is exposed over an area of 170,000 km² in northern Australia (Figure 1), there are reports of organic-walled microfossils showing low levels of thermal alteration (Croxford et al., 1973; Muir, 1974, 1976; J. H. Oehler, 1977; J. H. Oehler and Logan, 1977; D. Z. Oehler, 1978; Peat et al., 1978; Peat, 1979). In addition, shows of gas and bitumen have been reported from this basin (Muir et al., 1980) and some geochemical evidence presented suggesting that the McMinn Formation contains low-maturity rocks with moderate organic carbon concentrations (McKirdy, 1977; Peat et al., 1978).

There was clearly some interest in finding hydrocarbons in the McArthur Basin by Amoco Australia Ltd. who were actively assessing its potential during the course of this study and drilled a dry wildcat well. The potential of the basin was confirmed by the discovery of a small amount of oil in the Velkerri Formation during stratigraphic drilling by the Bureau of Mineral Resources, Geology and Geophysics (Jackson et al., 1986).

The exploration for hydrocarbons in the McArthur Basin and in other sub-greenschist facies Precambrian basins was hampered by the lack of certainty over the level of maturation of the organic matter. Indices which are used to determine

Figure 1. Locality map of the McArthur Basin, Australia.

maturation levels of organic matter in Phanerozoic rocks may behave quite differently in Precambrian rocks given the enormous amount of time between deposition and the present day, and the primitiveness of the source biota. Therefore, in order to improve the exploration effort for hydrocarbons in the McArthur and other Precambrian basins, an assessment of the two most commonly used maturation indices, reflectance and Tmax, and their relationship to the oil-window in the McArthur Basin was needed. Accordingly, the aims of this thesis are:

- 1) to petrologically characterise the organic matter within the McArthur Basin;
- 2) establish whether reflectances of this organic matter and the geochemical maturation index "Tmax", derived from Rock-Eval analysis, can be used to determine the maturity of the organic matter; and if so, to ascertain their relationship to the "oil-window" as conventionally defined in terms of vitrinite reflectance;
- 3) to assess the geological factors affecting its maturity, and
- 4) to compare modelled vitrinite reflectances derived from models of the geological history of the region with observed reflectances recalculated to equivalent vitrinite reflectances, and comment on the timing of hydrocarbon generation in the basin.

The area of study was restricted to the southern half of the McArthur Basin where all drill holes are located. The northern half is within the Aboriginal Reserve of Arnhem Land and access to this area is difficult due to its terrain and problems of gaining permission to enter from tribal elders.

CHAPTER 2

GEOLOGY OF THE McARTHUR BASIN

2.1 Introduction

The Middle Proterozoic McArthur Basin unconformably overlies the Early Proterozoic rocks to the west and north and the Early Proterozoic Murphy Tectonic Ridge to the east (Plumb et al. 1981). The basin is unconformably overlain to the north by sediments of the Palaeozoic Arafura Basin and to the south and east by the Palaeozoic Georgina and Daly River Basins (Figure 2-1). Scattered remnants of Cambrian volcanics and sediments and Cretaceous sediments unconformably overlie parts of the basin.

2.2 Stratigraphy

Sediments within the McArthur Basin are sub-greenschist facies and have a total thickness of up to 16.5 km (Plumb et al, 1981). Four major subdivisions are recognised in the southern McArthur Basin (Jackson et al., 1987a) - the Tawallah, McArthur, Nathan and Roper Groups, which are separated by regional unconformities (Figures 2-2, 2-3; Tables 2-1, 2-2). The Tawallah Group contains quartz-rich arenites with subordinate volcanics, carbonates, and lutites, and is up to 5.5 km thick. The McArthur Group is up to about 4 km thick and consists of interbedded carbonates and lutites with subordinate arenites and tuffaceous sediments. It is subdivided into two subgroups, the Umbalooga and Batten Subgroups, which are separated in

Figure 2-1. Structural map of the McArthur Basin showing the major tectonic units (after Plumb and Derrick, 1975; and Plumb and Wellman, 1987).

Figure 2-2. Geology of the southern McArthur Basin (after Jackson et al., 1987a)

places by an unconformity which is developed adjacent to and within major fault zones of a graben-like palaeogeographic feature, the Batten Trough.

The Nathan Group is up to 2 km thick and consists mainly of carbonates with minor lutites, arenites, rudites and volcanics.

The Roper Group is the youngest of all the groups and is up to 5 km thick. It consists of interbedded arenites and lutites with subordinate carbonate and oolitic iron formation. Jackson et al (1987b) comment that the type of sediments in the Roper Group is very different from the McArthur and Nathan Groups and that it may be appropriate to describe them as belonging to a different, as yet unnamed basin.

2.3 Intrusives

Laterally extensive dolerite sills consisting in places of five different sills with an aggregate thickness of 300 m intrude the Roper Group (Dunn, 1963). Tucker and Boyd (in press), interpreting aeromagnetic anomalies, conclude that elongate and widely spaced dykes occur over much of the McArthur Basin. Outcrop of one such transgressive dyke occurs along a minor fault line in the Roper Group (Dunn, 1963).

2.4 Age

Volcanics and granites in the Murphy Tectonic Ridge, which form the basement to the McArthur Basin, have yielded minimum radiometric ages of 1733 ± 20 m.y. for the Clifffdale Volcanics (Webb, in Plumb and Derrick, 1975) and about 1800 m.y. on the intrusive granites (McDougall et al., 1965). Page et al. (1984) comment that these igneous suites probably belong to the same magma generation event in the Kalkadoon-Leichardt Block to the south which yielded ages of between 1850-1870 m.y.

NORTHWEST		CENTRAL		SOUTHEAST	
MAIWOK SUBGROUP	CHAMBERS RIVER FORMATION		COBANBIRINI FORMATION		
	McMINN FORMATION	Bukalorkmi Sst Mbr	Sherwin Ironstone Member		
		Kyalla Mbr	"Cat Creek Mbr "		
		Moroak Sst Mbr	"Broadmere Sst Mbr "		
	VELKERRI FORMATION		"Lansen Ck Sh Mbr "		
BESSIE CREEK SANDSTONE					
CORCORAN FORMATION					
Munyi Member			ABNER SANDSTONE		
Hodgson Sandstone Member					
Jalboi Member					
Arnold Sandstone Member					
CRAWFORD FORMATION					
Wooden Duck Member			MAINORU FORMATION		
Mountain Valley Limestone Member			Kilgour Sandstone Member		
LIMMEN SANDSTONE					
"MANTUNGULA FM"					

Table 2-1. Stratigraphy of the Roper Group, southern McArthur Basin (after Jackson et al., 1987a,b).

K-Ar dating on sedimentary glauconites in the Tawallah Group gave minimum ages of 1,580 m.y. (Webb et al., 1963) and 1,590 m.y. (McDougall et al., 1965).

A model lead age of 1560 Ma from galena in the McArthur Group is given by Richards (1963) but because a model lead age is dependent on several parameters and assumptions, such an age has a margin of error of about 10 per cent (McDougall et al., 1965). A more precise age of 1690 ± 27 Ma has been derived from U-Pb zircon dating of tuffs in the Barney Creek Formation of the McArthur Group by Page (1981). Kralik (1982) gave a younger depositional age of 1537 ± 52 Ma for the Barney Creek Formation based

Figure 2-3. Schematic and interpretative NW-SE section showing the main stratigraphic and structural elements in the southern McArthur Basin (after Jackson et al., 1987a).

Figure 2-4. Schematic cross-section of the southern McArthur Basin at the close of Roper Group sedimentation (after Plumb, 1987).

NORTHWEST		CENTRAL		SOUTHEAST		
NATHAN GROUP			DUNGAMINNIE FORMATION		? ↑ ↓ ? KARNS DOLOMITE	
	Yalwarra Volcanic Member		BALBARINI DOLOMITE			
	Mt Birch Sandstone Member		Smythe Sandstone Member			
MCARTHUR GROUP	? ↑ VIZARD FORMATION ↓ ?	BATTEN SUBGROUP	LOOKING GLASS FM		AMOS FM	
			STRETTON SANDSTONE			
			YALCO FORMATION			
			LYNOTT FM	Donnegan Mbr	Hot Spring Mbr	Carabarini Mbr
	BARNEY CREEK FORMATION		REWARD DOLOMITE			
			HYC Puritic Shale Mb	Cooleu Dolomite Member		
			W-Fold Shale Mbr			
				Coxco Dolomite Mbr		
	EMMERUGGA DOLOMITE		TEENA DOLOMITE			
			Mitchell Yard Dolomite Mb			
			Mara Dolomite Mbr			
	UMBOLOOGA SUBGROUP		MYRTLE SHALE			
			LEILA SANDSTONE			
			TOOGANINIE FORMATION			
			TAToola SANDSTONE			
			AMELIA DOLOMITE			
			MALLAPUNYAH FORMATION			
	MASTERTON SANDSTONE					
	TAWALLAH GROUP				HOBBLECHAIN RHYOLITE	
			GOLD CREEK VOLCANICS			
WUNUMANTYALA SANDSTONE			WOLLOGORANG FM			
SETTLEMENT CREEK VOLCS			AQUARIUM FM			
SLY CREEK SANDSTONE			McDERMOTT FM			
SEIGAL VOLCANICS						
YIYINTYI SANDSTONE			WESTMORELAND CONGLOM			

Table 2-2. Stratigraphy of the Tawallah, McArthur and Nathan Groups, southern McArthur Basin (after Jackson et al., 1987b).

on Rb-Sr measurements on <2 μ m illites and carbonate leachates but Page et al (1984) would interpret Kralik's data as a minimum age. Kralik (1982) also refers to unpublished data of his which suggest a Rb-Sr age of 1589 ± 28 Ma from tuffs in the McArthur Group.

A minimum age of 1390 Ma was obtained from glauconites in the uppermost unit in the Roper Group (Crawford Formation) using the Rb-Sr method (McDougall et al., 1965). Kralik (1982) derived an age of 1429 ± 31 Ma from a Rb-Sr isochron of illites in the McMinn Formation of the Roper Group, an age which Page et al. (1984) consider to be a minimum age.

Dates of 1220 and 1280 Ma were obtained from plagioclase in two dolerite sills in the Roper Group using the K-Ar method whereas co-existing pyroxene from one of the samples gave an age of 1150 Ma (McDougall et al., 1965). However, as McDougall et al. (1965) point out, the difference between the measured ages for co-existing plagioclase and pyroxene shows that some argon loss has occurred and these ages are therefore minimum ages.

In broad terms then, the McArthur Basin was formed after 1870 Ma and deposition was completed before 1280 Ma. More specifically, using the best available ages, the Barney Creek Formation in the McArthur Group has a depositional age of 1690 ± 27 Ma (Page, 1981) and the Roper Group has a minimum depositional age of 1429 ± 31 Ma (Kralik, 1982).

2.5 Depositional Framework and Tectonics

The depositional framework of the basin was dominated by a northerly-trending intracratonic graben, the Batten Trough (Plumb and Derrick, 1975), which was 50 - 80 km wide by 600 km long. In this graben very much thicker successions (up to 12 km) accumulated than on the stable shelves on either side (Plumb et al., 1980). About 4 km of sediments accumulated on

the Bauhinia and Wearyan Shelves and up to 9 km on the far western Bauhinia Shelf (Jackson et al., 1987a). An even thinner sediment cover accumulated over a westerly trending basement high, the Urapunga Tectonic Ridge, which separates the Arnhem Shelf from the Bauhinia Shelf. Later tectonic activity resulted in deformation and uplift of the Batten Trough to produce the presently observed Batten Fault Zone (Plumb et al., 1980). Similarly, later tectonic activity occurred along the Urapunga Tectonic Ridge and formed the Urapunga Fault Zone (Plumb et al., 1980). The southern part of the Batten Trough was probably a half-graben (Jackson et al., 1987a) in which maximum subsidence was near its eastern margin, which is poorly defined by the Emu Fault Zone, and there is good sedimentological evidence of fault movement near this zone during deposition of the Barney Creek and Lynott Formations and the Stretton Sandstone (Jackson et al., 1987a).

Muir (1983a) comments that the sediments of the McArthur Basin were deposited in a number of northerly trending half-grabens with the greatest subsidence during deposition taking place in the western areas of the half grabens, but that the overall pattern as given by Plumb et al. (1980) remains essentially correct. Complex block-faulting has resulted in locally steeply dipping strata adjacent to faults whereas elsewhere dips are generally very shallow (Plumb et al., 1980; Muir, 1983a). Plumb and Wellman (1987), in interpreting regional gravity and magnetic anomalies in the basin, consider the Batten Trough is separated by the Urapunga Tectonic Ridge and have redefined the northern part of the trough as the Walker

Trough. They propose an east-west extension model, related to block rotation and accommodation by north-west transfer faults to explain the development of the Batten and Walker Troughs.

The McArthur Basin, therefore, probably formed in response to lithospheric stretching, in a manner similar to the model proposed by McKenzie (1978). Such rift basins are unconformably overlain by gently dipping, more laterally continuous strata of the post-extension, thermal subsidence or sag phase (McKenzie, 1978). The Roper Group clearly was deposited during this phase as it contains generally shallow dipping strata and as Plumb et al. (1980) point out, many of its units show a remarkable lithological consistency over hundreds of kilometres. In contrast, the older McArthur and Nathan Groups show marked rapid facies changes, with few formations showing lithological consistency over tens of kilometres (Jackson et al., 1987b). The Roper Group's depocentre is in the southwest, the Beetaloo Sub-basin (Plumb and Wellman, 1987), where over 3 Km of the lower Roper Group were deposited. The sequence thins eastwards on to the Wearyan Shelf, and northwards on to the Urapunga Tectonic Ridge; further north the sequence thickens, and probably exceeded 2 km prior to the erosion of the Maiwok Subgroup (Jackson et al., 1987b).

2.6 Depositional Environments

The Tawallah Group sediments were deposited in a variety of environments ranging from shallow marine to continental (Jackson et al., 1987a). Lava flows and pyroclastics are relatively common on the Wearyan and Arnhem Shelves, but

decrease significantly in the southern Batten Trough (Plumb et al., 1981).

The McArthur Group is characterised by sediments containing evidence of having formed under evaporitic conditions which are mostly interpreted as being continental (lacustrine), although sediments formed in shallow marine to sabkha-like environments are present in lesser amounts (Jackson et al., 1987a). One formation in particular, the Barney Creek Formation has been intensively studied as it hosts a number of base-metal deposits including a major Pb-Zn deposit, the H.Y.C. deposit (summary in Jackson et al., 1987a). Latest studies of the Barney Creek Formation in the vicinity of the H.Y.C. deposit, indicate deposition in a saline lake or nearshore lagoon complex that was developed on the eastern shore of the Batten Trough, at a time when the major eastern bounding fault zone, the Emu Fault Zone, was active, resulting in deeper water turbidites to shallow-water to emergent sediments similar to those found in sabkhas and saline lakes (Williams and Logan, 1981; Logan and Williams, 1984).

To the south of the H.Y.C., the Barney Creek Formation was deposited in a 20 by 7 km trough (the Glyde River subbasin, Figure 2-2) whose dimensions were controlled mainly by northerly faults which together with cross-cutting easterly faults were also active at the time of deposition (Dashlouty and Davidson, 1986). Abundant air-fall and detrital volcanic material, up to about 50 m in thickness, occurs at the base of the Barney Creek Formation which grades upwards over an interval of less than 10 m into up to 70 m of carbonaceous shale

(Dashlouty and Davidson, 1986). Overlying this sequence are up to ca. 800 m of mainly carbonate-rich turbidite beds, generally less than 10 cm thick and commonly comprising fine-grained dolarenite grading into dolutite. Coarser-grained dolarenites and lithic dolarenites (containing clasts up to 1cm long) are less common, and comprise less than ca. 20% of this sequence. Tuffaceous material is present within this sequence and its proportion increases markedly to the south until 17% of the total sequence is volcanoclastic, implying a proximal volcanic source (Dashlouty and Davidson, 1986).

The Nathan Group sediments have mostly formed in a playalake type environment (Balbarini Dolomite) but sediments at the top of this group (Dungaminnie Formation) may have been deposited in tidal to deeper marine conditions (Jackson et al., 1987b).

The basal unit of the Roper Group (Limmen Sandstone) was formed in fluvial conditions whereas most of the remaining units were formed in marginal to deeper marine conditions (Jackson et al., 1987b). The predominately fine-grain units (Mainoru, Corcoran and Velkerri Formations) are considered by Jackson et al. (1987b) to have formed in deeper open marine conditions whereas sulphur isotope values of pyrite from the upper half of the Velkerri Formation indicate that sulphate in the depositional waters was commonly limited and therefore the sediments could not have formed in open marine conditions where there is an unlimited supply of sea water sulphate (Donnelly and Crick, 1988). Such an environment may have been a barred marine basin that was occasionally breached.

Millimetre-sized calcareous and/or pyritic discoidal shapes, randomly orientated in silty mudstone, and occasionally displaying cruciform twinning occur in one bed within the Velkerri Formation (Plate 30,e) and similar forms, displaying, in places, rosettes, occur also in one bed in the "Lansen Creek Shale" (Plate 39, A,B) which is stratigraphically equivalent to the Velkerri Formation (Jackson et al., 1987b). These discoidal shapes and their rare cruciform twins and rosettes, are typical of gypsum which has formed interstitially in pre-existing sediments (Muir, 1979), and were later replaced by carbonate and/or pyrite. These early diagenetic pseudomorphs after gypsum indicate that the depositional environment was hypersaline for at least part of the time. The pseudomorphs were observed in two drill holes (Urapunga 3, and 82/1), which are separated by about 250 km, indicating a widespread hypersalinity event consistent with the suggested depositional environment being, at times, a barred basin.

2.7 Occurrences of hydrocarbons

There is abundant evidence of the presence of hydrocarbons in a number of formations in the Roper and McArthur Groups (summarised in Jackson et al., 1987b).

The first report of the presence of hydrocarbons is given by Wade (1926) who found bitumen, which probably emanated from the Roper Group, impregnating vesicular basalt (Cambrian Antrim Plateau Volcanics) at its junction with quartzites, shales and flags (Roper Group) near the Waggon Lagoon on the Roper River.

Bitumen was found in intergranular pores, vugs, microfaults, joints and stylolites within silicified carbonates of the Looking Glass Formation of the McArthur Group together with a dark brown viscous liquid which was probably liquid hydrocarbon (Muir et al., 1980). The bitumen in the vugs occurred as globules which were mainly shiny and black on the outside but dark brown and crumbly when freshly broken and were not soluble in trichloroethelyne, or black, hard and shiny with a conchoidal fracture and were soluble in trichlorethylene.

Bitumen also occurs in the Yalco Formation, Stretton Sandstone and the Looking Glass Formation of the McArthur Group and in the Broadmere Sandstone in the Roper Group (Womer, 1986). In the Yalco Formation the bitumen formed thick coatings lining vuggy pore walls and in places was in contact with euhedral crystal terminations of authigenic quartz lining the vug suggesting the bitumen post-dated the growth of the secondary quartz. A similar relationship was observed in the Stretton Sandstone but the bitumen was also cracked in places and the cracks filled with sparry dolomite. The cracking was probably caused by loss of light ends from the bitumen and the circulating waters deposited the sparry dolomite after the reservoir was breached. Bitumen partly fills primary pore spaces in the Broadmere Sandstone and in places has also formed shrinkage cracks that are filled by dolomite, but secondary quartz crystal faces in the pore spaces are commonly curvilinear where in contact with the bitumen suggesting that the hydrocarbons inhibited crystal growth. Womer (1986) considers that the bitumen in the Broadmere Sandstone Member

of the Cobanbirini Formation had formed from hydrocarbons that migrated into the formation and was degraded following breaching of the reservoir and subsequent flushing with meteoric waters.

Oil bled from drill core of the Barney Creek Formation exposed to sunlight from a Kennecott mineral exploration hole (Gallagher and MacKay, 1981). Gas, composed mainly of methane (74.25%) and ethane (10.25%), and probably sourced from the Coxco Dolomite Member which contained degraded crude oil trapped in fractures, also flowed from the same drill hole (Gallagher and MacKay, 1981). Oil bubbled from thin laminae of siltstone enclosed in black mudstone over a 0.1 m interval in the Velkerri Formation of the Roper Group (Jackson et al., 1986).

CHAPTER 3

METHODOLOGY

3.1 Samples

All rock specimens examined in this study came from diamond drill core and in one case, from rock chips derived from the unsuccessful wildcat oil-exploration well, Broadmere 1 (Appendix A). There is an abundance of diamond drill core from the southern McArthur Basin particularly from the Batten Trough which has been intensively drilled in places by mineral exploration companies mostly looking for base-metal mineralisation of the kind found at the HYC deposit (Figure 3-1). This stratiform deposit has 227 million tonnes of ore with an average grade of 9.2% Zn, 4.1% Pb and 41 g/t Ag but has yet to be exploited as no commercially viable process has been developed to extract the metals (Buchanan, 1984). In addition, Amoco Oil Exploration, commenced a regional survey of the McArthur Basin in 1980 which resulted in their drilling a number of stratigraphic holes and culminated with the wildcat dry oil-well, Broadmere 1, in 1984. Six shallow stratigraphic wells were drilled by the BMR in 1983 and 1984 as part of a project to examine the sedimentology of the Roper Group.

3.2 Measurement of geothermal gradients

In 1982 Amoco Australian Petroleum Company drilled eight stratigraphic holes (82/1 - 82/8) in the McArthur Basin, one of which (82/8) had to be plugged upon abandonment due to strong artesian flow. I measured the downhole temperatures of two of these (82/5, 82/7) in August, 1983, by which time the

downhole temperatures had stabilized (Plate 1b). Equipment failure prevented any more holes being measured.

The equipment used was a water-tight probe containing a thermistor (Fenwal, type UUA33J1) attached to about 500 m of cable on a portable drum. The probe was lowered down the drill hole and measurements made at 10 m intervals. A BMR-designed Wheatstone bridge was used to measure the change in resistance of the thermistor which was calibrated in the laboratory. Calibration errors and subsequent thermistor drift can contribute uncertainties of 0.01°C in absolute readings of temperature but, for determinations of thermal gradient, only the relative values are important (Cull and Sparksman, 1977). The performance and water-tightness of the equipment was checked down a test well prior to going into the field. A maximum thermometer was attached to the probe as a back-up and further in-field check of the equipment. Once the probe had reached the bottom of the DDH it was left there for 5 minutes to allow sufficient time for the maximum thermometer to equilibrate before the probe was hauled up.

3.3 Screening of samples: Rock-Eval and Total Organic Carbon analyses

Rock-Eval and total organic carbon (TOC) analyses were done in the Organic Geochemistry Laboratory, Bureau of Mineral Resources, Geology and Geophysics (BMR), Canberra, on all specimens collected from the McArthur Basin. The results were used initially as a guide to selecting specimens for petrographic analyses.

Approximately 100 milligrams of rock powder was loaded into a stainless steel crucible and a series of samples (up to 18 at one time) was then automatically run through the machine (Rock-Eval II), starting each run with a standard followed by a blank.

Each sample was initially heated at 300° C for 5 minutes and the amount of hydrocarbon released recorded as the S1 value in milligrams per gram of sample. The S1 value indicates the amount of free hydrocarbons below about C₃₀ (Espitalie et al., 1986). The sample was then heated further at 25 C°/min. up to 550° C where it was left for 1 minute. The amount of hydrocarbon generated during this cycle from kerogen cracking and from the volatilization and cracking of heavy extractable compounds such as resins and asphaltenes (Espitalie et al., 1986), was recorded as the S2 value (mg/gm). The amount of CO₂ generated from the cracking of kerogen (Espitalie et al., 1986) whilst the sample was at 300° to 390° C, was recorded as the S3 value (mg/gm). During pyrolysis, water, carbon monoxide and carbon dioxide is generated from organic matter but the amount of water given off is completely masked by water set free by the thermal decomposition of a number of minerals (Espitalie et al., 1986). Only carbon dioxide is measured as carbon monoxide is difficult to trap and then only up to a maximum temperature of 390° C as carbon dioxide can be generated from the thermal decomposition of siderite at temperatures above 400°C (Espitalie et al., 1986).

Figure 3-1. Location of drill holes in the McArthur Basin sampled in this study. For location of drill holes in the Glyde River Subbasin, see Figure 3-2.

Figure 3-2. Location of drill holes (GR1-5, GR7-11) in the Glyde River Subbasin together with the surface geology of the region (after Smith, 1964; and Plumb and Rhodes, 1964)

For TOC analyses, a 50:50 mixture of conc. HCl and distilled water was slowly added to 200 mg of rock powder until effervescence ceased and the mixture was heated at 60° C for 1 hour and allowed to cool. The mixture was then filtered, washed with distilled water until neutral and dried at 60° C for 12 hours. The amount of TOC was determined using a Leco DC12 analyser.

3.4 Preparation of rock specimens for microscopic examination

Rock specimens were prepared for microscopic examination by mounting in cold-setting polyester resin mixed with one and a half to two percent hardener. Polished surfaces were then produced by a number of steps:

- 1) water-wet grinding using 120 then 180 size grit on rotary laps,
- 2) water-wet grinding using 320, 400 and finally 600 grit by hand,
- 3) polishing on rotary laps first with chromium sesquioxide (7 micron) and then with polishing grade magnesium oxide,
- 4) a final buff with a wet selvylt cloth and the specimen was rinsed with distilled water before drying.

3.5 Microscopic examination

The specimens were initially examined using a binocular (up to x40 magnification) to assist in lithological description and to check the location of any organic matter. A drop of dilute HCl acid was placed on the edge of specimens as a matter of course to check for the presence of carbonates. A modified Leitz

Panphot microscope mounted with a Wild MPS45 automatic 35 mm camera was also used for low magnification observations (x10 to x100) of polished blocks using oblique incident white light (tungsten bulb with blue filter) and normally incident blue/ultraviolet light from a 150W Zenon lamp with a BG12 filter. Observations and photographs in fluorescence mode were made through a TK400 dichroic mirror and a K510 barrier filter.

High magnification observations (x320, x500, x1250) and photographs were made through a Leitz Orthoplan Pol microscope in both reflected white and blue/ultraviolet light modes. The ultra-violet light source was a 100w mercury vapour lamp and the light was passed through a BG3 (UV) filter and a BG38 (Blau) red-suppression filter. Observations and photographs in fluorescence mode were made through a TK400 dichroic mirror and initially through a K490 barrier filter but mostly with a K510 barrier filter. Photographs were taken with a manual 35 mm Leica mounted on an MPV1 photometer which was initially used to measure light intensities after taking some calibration films, but most light readings were obtained by use of a Leitz light-meter which could be mounted on the eye-tube, after removing the eye-piece.

A mirror housing attached to the rear of the microscope allowed easy switching from three light sources: 1) a 100 watt quartz-iodide lamp for general white-light observations, 2) a 100 watt quartz-iodide lamp that had a stabilized power source, for reflectance measurements and 3) a 100 watt mercury vapour lamp which had a stabilized power source, for general observations in fluorescence mode and for intensity and spectral measurements.

3.6 Reflectance measurements

Reflectance measurements were made with a Leitz MPV-1 photometer, mounted on a Leitz Orthoplan Pol microscope, using monochromatic light at 543 nm (band-width = 22 nm) and calibrated by McCrone Specular Reflectance Standards (spinel - 0.416%, yttrium aluminium garnet - 0.916%, and gadolinium gallium garnet - 1.710% reflectance). Starting procedures, microscope adjustment, illumination, alignment and the degree of stability of the apparatus were done in accordance with the standards laid down by the International Committee of Coal Petrology. The MPV-1 photometer, which had only about 5 hours use prior to this study (D. Burger, pers. comm.) was initially checked for performance before being used, and was found to perform within the manufacturer's specifications.

Maximum and minimum reflectance measurements were made at a room temperature of $23^{\circ}\text{C} \pm 1^{\circ}\text{C}$ by rotating the stage through 360° and recording the two maxima and minima provided the two maxima or minima readings were within $\pm 5\%$ relative of each other. All measurements were made through a x50 oil objective using Leitz Immersionsoel (DIN 58884), $n_{23} = 1.5180$. An illuminated field of 0.03 mm square was used and the measuring field was set at 0.001 mm square.

Reflectance measurements made on thucholites were taken one micron inside a well-defined edge of the thucholite and a maximum of four measurements taken about 90 degrees apart were made on each thucholite.

A x120 objective was initially experimented with for taking reflectance measurements, as much of the organic matter in the

McArthur Basin presents very small areas suitable for measuring, but the results were not acceptable as the centering and levelling accuracy of the stage during rotation, even after the most careful adjustment, was poor. Even so, the process of keeping the measuring field over the same area whilst rotating, using a x50 objective, was time-consuming and required patience and delicate manipulative skills. Manfred Look, Chief Technician from Wild-Leitz (Australia), checked the levelling of the stage on two occasions, and could offer no solution for improving the centering or levelling of the stage as it appears that both features are, in the final analysis, a function of the accuracy tolerances in the manufacture of the stage and its support.

3.7 Fluorescence measurements

Measurement of the intensity of fluorescence (I) was made using a 543 nm interference filter (band-width = 22 nm) on the MPV1 photometer, and the red-green quotient (Q) was made using a 643 nm (band-width = 23 nm) and 504 nm (band-width = 20 nm) interference filters. A Leitz fluorescence standard (uranyl-glass) which emits a yellow-green fluorescence was used for calibration and measured using the 543 nm filter. Although it would have been desirable to do reflectivity and fluorescence measurements together, the aperture of the measuring field used for reflectance measurements generally did not allow sufficient light through to the photometer from the uranyl-glass standard. Increasing the high-voltage supply to the photometer to increase its sensitivity and using the same measuring field as for

reflectance measurements, resulted in unacceptably high dark-current fluctuations from the photometer, so the measuring field was increased to 0.01 mm square. Calibration of the photometer against the standard was done regularly, at least every 15 minutes as the higher voltage needed for the photometer resulted in some drift. In the case of measuring the alteration of intensity at 546 nm with time, the standard was measured at the beginning and end of the 30 minute period and the intensity values obtained from the standard at the beginning and at the end were those used to calculate the organic matter intensity. In all measurements of fluorescence the barrier filter was removed but the TK400 dichroic mirror left in. Alignment of the measuring aperture was made initially with the barrier filter in and a final alignment made with it out, as removal of the barrier filter resulted in a slight shift of position of the the area to be measured.

3.8 Statistical analysis and graphing of reflectance and fluorescence measurements

Measurements of reflectance and fluorescence were statistically analysed using a Hewlett-Packard Statistical Analysis Pac, Series 80, on a Hewlett-Packard 86 bench-top computer. The mean value, 95% confidence limits of the mean, and range were plotted using a MacIntosh personal computer and associated software. Showing the 95% confidence limit of the mean on graphs of reflectance or fluorescence for individual drill holes provides some constraint on the plotting of trend-lines and gives an indication of how significantly one data set varies from another (at the 95% confidence level).

3.9 Preparation of macerations

A number of maceration procedures have been proposed (e.g. Staplin et al., 1960) but the choice of procedures depends largely on how quickly one requires maceration to take place; the quicker it is, the more likely the process will destroy delicate organic structures. Crushing the initial rock samples will obviously destroy large specimens and using hot or boiling reagents to speed up solution of the mineral matter may lead to carbonisation (Peat, 1979).

The procedure used in this study was similar to that used by Peat (1979) who developed the gentlest possible method to conserve most of the organic matter for his micropalaeontological study of the Roper Group.

The procedure used was:

1. Samples of core without any fractures were cut to about a 1 cm. size cube and the surfaces hand ground to remove surface contamination.
2. The cube of rock was washed with distilled water and placed into a clean polypropylene beaker and then covered with concentrated HF. The beaker was then covered with a clean polypropylene dish.
3. The HF was topped up every few days and maceration was complete after about 3 weeks.
4. The macerate was washed in distilled water and placed in a polypropylene centrifuge tube and given a gentle centrifuge for about 5 minutes. After centrifuging, the distilled water was decanted and more distilled water added. The tube was gently shaken, and then gently centrifuged for another 5 minutes. After

repeating this process about 5 times until the solution was neutral to litmus paper, the macerate and some of the distilled water was placed in a small clean glass container and a few drops of formalin added to prevent fungal growth (M. Owen, pers. comm.), and sealed with a plastic snap-top.

5. Strew mounts of macerates were prepared by placing several drops of glycerine on a clean slide and using a disposable clean Pasteur pipette to transfer some of the macerate (after shaking the bottle to make sure of obtaining a representative sample). A clean cover-slip was placed over the macerate and the slide placed upside down and gently pressed to disperse the organic matter. A coating of nail varnish was applied to the edges of the cover-slip to prevent dehydration.

3.10 Scanning electron microscopy, electron probe analyses and X-ray mapping

Use of the scanning electron microscope was limited to the examination of macerates and some rock specimens to gain some idea of their physical structure at high magnifications and to undertake electron probe analyses and X-ray mapping to check the composition of organic and mineral matter in selected specimens.

In scanning electron microscopes, an extremely finely focussed electron beam is scanned across a specimen and a signal produced by the incident primary beam is picked up by a detector and displayed as a brightness variation on a synchronously scanned cathode-ray tube (CRT) to form an image.

The interaction of the primary beam with the specimen generates secondary electrons, back-scattered electrons, X-rays and other effects as shown in Figure 3-3.

Figure 3-3. Signals emitted by a specimen by interaction with incident electron beam in a scanning electron microscope (modified from Jeol Ltd. JSM-35 Scanning Microscope Instructions).

Image magnifications are simply given by the ratio of the scanned length on the CRT to that on the specimen, and can be varied from about 10 times to 100 - 200 thousand times. Using secondary electron images has the twin advantages of high resolution and great depth of field. In practice it was found that the particular scanning electron microscope used in this study, a Jeol, model JSM-35, which is one of the earlier models, had poor resolution above about 10 thousand times despite much effort to "fine-tune" it.

Secondary electron images show mostly variations in surface topography and some compositional variations whereas

backscattered electrons produce images more related to marked compositional contrast than to topographical variations. Minerals composed of light elements appear darker than those composed of heavier elements in images produced by backscattered electrons (Robinson and Nickel, 1979; Robinson, 1980; Hall and Lloyd, 1981).

X-ray emission is measured using an X-ray Energy Spectrometer, in this case a Kevex, model 5100, and displayed on a CRT as an X-ray energy spectrum. The elements that are present are identified by the location of their energy peaks along the horizontal axis, in this case using a program associated with the instrument that superimposed the major spectral lines for selected elements over the spectral display. The accuracy of the identification system was occasionally checked by examining the spectral lines of pyrite, which was commonly present in the specimens examined. In the period that I used the instrument the identification program was always well calibrated and did not require adjustment. X-ray mapping of selected elements was achieved by selecting the area under their major energy peaks on the CRT.

The macerates used in this part of the study were transferred from their containers using clean Pasteur pipettes onto aluminium stubs and allowed to dry within a vacuum evaporator before coating with gold. Better electrical and thermal conductive properties are achieved with gold than carbon thereby giving sharper secondary electron images although carbon coatings are preferable for X-ray analyses (Goldstein et al., 1981). Carbon coatings were used on the polished blocks selected for X-ray analyses. The aluminium

stubs and polished blocks were carefully glued to a brass holder using colloidal graphite which gives good conductivity and allows any electrical charge built up on the specimen to dissipate.

Some of the polished blocks had to be trimmed with a diamond saw to fit into the SEM and care had to be taken with specimens previously examined using oil-immersion objectives, that any immersion oil had been removed by cleaning with light petroleum. Immersion oil can contaminate the SEM vacuum chamber, and can give spurious results during X-ray analysis. On one occasion, immersion oil seeped from a microfracture in a polished block and gave an initially quite puzzling, strong chlorine peak.

3.11 Extracts

Samples were selected following initial screening for organic carbon content and maturity by Rock-Eval and TOC analyses. The samples were crushed, and organic matter extracted and fractionated by liquid chromatography into saturated, aromatic and ONS compounds using standard procedures (Powell, 1982) by the Organic Geochemistry Laboratory of the BMR. Some aromatic fractions were subdivided into monoaromatic, diaromatic and triaromatic fractions by HPLC techniques (Boreham and Powell, 1987) and the triaromatic fraction was analysed by capillary gas chromatography (Boreham and Powell, 1987) to determine Methyl Phenanthrene Indices (Radke and Welte, 1983).

3.12 Elemental analysis

Kerogen was obtained from selected samples by acid digestion of extracted rock samples using standard procedures (Durand and Nicaise, 1980), and the analyses were made by AMDEL in Adelaide.

3.13 Photographic film and processing

Ektachrome ASA400 colour slide film was used for all photomicrographs. Processing of the film and producing colour positive prints was done by Canlab, Canberra, who, during the course of preparing this thesis, changed the size of their colour prints which resulted in some plates having odd-sized individual photomicrographs. The colour plates were produced from colour negatives by Bica. The black and white plates were photographed and processed by Photopol. All SEM photographs were made using Polaroid film.

CHAPTER 4

CLASSIFICATION AND NOMENCLATURE OF ORGANIC MATTER IN GEOLOGICAL FORMATIONS

4.1 Introduction

The nomenclature adopted for describing organic matter in the McArthur Basin need not be related to any existing nomenclature system. This extremely ancient organic matter may be so completely different that a entirely new nomenclature system may have to be erected. However, it may have identical or similar characteristics to some forms of organic matter found in Phanerozoic rocks and therefore some existing terms could justifiably be used.

A large number of terms, currently used to describe naturally occurring organic substances, have originated from well in the past. Asphalt, for example, is a term originating from the Sumerians who lived in the Euphrates Valley in Iraq about 3800 to 2500 BC and the expression "bitumen" is apparently derived from the Sanskrit language (Forbes, 1936, in Abraham, 1963). A large number of currently used terms (e.g. ozokerite (modern spelling now - ozocerite) grahamite, gilsonite, wurtzilite) originated from Europe and the United States during the nineteenth century with the various substances being described usually in terms of appearance, hardness and for some, odour (summarised in Abraham, 1963).

4.2 "Global" Classification Schemes

One of the earlier well-known schemes, was developed by Herbert Abraham who collated all reports on naturally occurring organic substances from around the world and produced a classification scheme wherein all such substances were either "bitumens" or "pyrobitumens" (Abraham, 1963) (Table 4-1). He defines "bitumen" as "a generic term applied to native substances of variable colour, hardness and volatility; composed principally of hydrocarbons, substantially free from oxygenated bodies; sometimes associated with mineral matter, the non-mineral constituents being *fusible* and largely *soluble* in carbon disulphide, yielding water-insoluble sulfonation products". He includes in this definition petroleums, defined as basically being a liquid, and native mineral waxes and asphaltites (gilsonite, glance pitch and grahamite). Petroleum is not fusible and therefore conflicts with his definition of bitumen. Pyrobitumen is "a generic term, applied to native substances of dark color; comparatively hard and non-volatile; composed of hydrocarbons, which may or may not contain oxygenated bodies; sometimes associated with mineral matter, the non-mineral constituents being *infusible* and relatively *insoluble* in carbon disulphide". He states that "this definition includes the asphaltic pyrobitumens (elaterite, wurtzilite, albertite and impsonite) also the non-asphaltic pyrobitumens (peat, lignite, bituminous coal and anthracite coal) and their respective shales". The inclusion in the term

A. BITUMEN - FUSIBLE AND LARGELY SOLUBLE IN CARBON DISULPHIDE	
GROUP	MEMBERS
Petroleums (liquid)	Non-asphaltic petroleum Semi-asphaltic petroleum Asphaltic petroleum
Native Asphalts	1. Pure or fairly pure 2. Associated with mineral matter, e.g. "rock asphalt"
Native mineral waxes	Ozokerite Montan wax
Asphaltites	Gilsonite Glance Pitch Grahamite
B. PYROBITUMEN - INFUSIBLE AND RELATIVELY INSOLUBLE IN CARBON DISULPHIDE	
GROUP	MEMBERS
Asphaltic Pyrobitumens	Elaterite Wurtzilite Albertite Impsonite Asphaltic pyrobituminous shales
Non-asphaltic Pyrobitumens	Peat Lignite Bituminous Coal Anthracite Coal Coaly Shales

Table 4-1 Classification of naturally occurring organic matter, after Abraham (1963).

Table 4-2. Terminology and clasification of naturally occurring bituminous substances, after Hunt et al. (1954).

Table 4-3. Terminology and classification of naturally occurring bitumens and related substances, after Wen et al. (1978). (Author's note: oil-shales having high vitrinite or bituminite have high N, cf. Hutton et al., 1980)

"bitumen" of coals and related types of organic matter is clearly at variance with accepted common usage.

Hunt et al. (1954) modified Abraham's classification scheme so that the distinction between bitumen and pyrobitumen is based solely on solubility in carbon disulphide thus eliminating the problem concerning the classification of petroleum (Table 4-2). Wen et al. (1978) prefer a classification scheme based on Abraham's but split the classification of petroleum into two groups based on how much nitrogen they contain and add another group called "kerogen" (Table 4-3).

A committee, formed following a resolution passed at the Third World Petroleum Congress to propose definitions and simple methods of analyses of the various kinds of organic matter occurring in geological formations, presented a classification scheme which has three major categories, to the Fifth World Petroleum Congress (Louis et al., 1959) (Table 4-4). The committee comments that the criteria used "are of a physico-chemical nature" and that "because of this, products of geologically different development may be classified in one group and vice versa."

King et al. (1963) proposed a genetically based classification scheme for all organic matter contained in geological formations with the major division being made on whether the organic matter was syngenetic or epigenetic (Table 4-5). Under this classification scheme all the bitumens and the asphaltic pyrobitumens of Abraham's are considered to be epigenetic. A number of researchers follow this classification

GROUP	MEMBERS
NAPTHABITUMEN (Substantially soluble in carbon disulphide)	Natural gas of petroleum Crude Oil Natural Asphalt Ozokerite Asphaltite
NO CATEGORY	Asphaltoid - a black or dark brown structureless substance, insoluble in carbon disulphide, probably had migrated in the past.
KERABITUMEN (substantially insoluble)	Organic matter of muds Organic matter of source beds Organic matter of oil shales (Kerogen)
COAL (substantially insoluble)	Sapropelic coal Humic coal

Table 4-4. A classification scheme of sedimented organic matter and derived products, after Louis et al. (1959).

scheme referring to the epigenetic group as "bitumen" and commonly only referring to the solid bitumens within this group (e.g., Jacob, 1976, 1981; Curiale, 1985). Hunt (1979), in a modification of his earlier classification scheme (Hunt 1954), also subdivides coals and natural bitumens into two major groups depending on whether they are allochthonous or autochthonous (Table 4-6).

ORGANIC MATTER IN GEOLOGICAL FORMATIONS

Table 4-5. Classification scheme for organic matter in geological formations (after King et al. 1963).

However, petroleum-like substances have been observed in coals by M. Teichmuller (1974) who used the term "exsudatinite" to describe the organic matter that showed in fissures and pores of sub-bituminous and high-volatile bituminous coals which fluoresced when irradiated with short wavelength light.

Table 4-6. Classification of natural bitumens and coals (after Hunt, 1979).

Exsudatinite generally occurs in veins, wedge-shaped cracks, infilling bedding-plane joints or infilling empty cell lumens or is found interstitially in pyrite concretions (Cook and Kantsler, 1982). Stach et al. (1982) also call exudates "bitumen" and comment that it begins to form during the sub-bituminous coal stage. On further coalification the newly formed bitumen is cracked into hydrocarbons of smaller molecular size on the one hand, and into strongly reflecting, polycondensed, residual products on the other. Exsudatinite has only been observed in humic coals and not in rocks containing organic matter derived from algae (Robert, 1980).

Some researchers (e.g. Tissot and Welte, 1978) follow strictly chemical criteria for classification of organic matter and define bitumen as being soluble in normally used organic

solvents which since the 1970's or thereabouts does not include carbon disulphide. Huizinga et al. (1987) define bitumen for the purposes of their study "as the organic material that is generated from the thermal maturation of kerogen and soluble in a 9:1 dichloromethane/methanol mixture". They recognize two categories of bitumen, "bitumen-1" and "bitumen-2". "Bitumen-1" they define as "organic products that are readily extractable from the kerogen or kerogen plus mineral matrix" while "bitumen-2" refers to "organic products that are strongly adsorbed on the mineral matrix" and therefore "requires the destruction of the constituent minerals for the organic material to be solubilized". The term "bitumen" in this context means any extractable organic matter and therefore substances commonly referred to as bitumens which are insoluble, such as impsonite, wurtzilite and albertite, are excluded.

Jacob (1976, 1981) considers that the most important characteristic for distinguishing solid bitumens from coal under the microscope is "in general their passive behaviour with respect to their form" i.e. the variety of morphological form. Jacob (1976) gives examples of the variety of shapes bitumen may form, such as an evenly flat body with its edges defined by the crystal faces of quartz or carbonate or as "microplates" infilling cavities or fissures, infilling cavities in microfossils such as foraminifera or commonly forming very diffuse masses or rare, but typically globular bodies, in silty, marly or clayey rocks.

4.3 Bitumen associated with radioactive elements

Many terms that have been proposed to describe solid bitumens associated with radioactive elements are not included in most of the global classification schemes reviewed in the previous section. In particular, a commonly used term "thucholite" is conspicuous by its absence in all classification schemes except that of King et al. (1963). Ellsworth (1928) coined the term to describe radioactive, carbonaceous, irregularly rounded nodules or more or less roughly globular masses from 1 mm to 1 inch (sic) in diameter within a pegmatite dyke in Ontario, Canada. Thucholite, as defined by Gary et al. (1974), is a "brittle jet-black mixture or complex of organic matter (hydrocarbons) and uraninite, with some sulphides, occurring especially in gold conglomerates (as in those of the Witwatersrand of South Africa) or in pegmatites (as in Canada); it may contain up to 48% thorium". Thucholite, occurring mainly in conglomeratic beds of the Witwatersrand system and commonly containing inclusions of uraninite, consists of small granules (up to 1.4 mm in diameter) or columnar and massive thucholite up to several millimeters in size (Liebenberg, 1955).

Other terms used to describe organic matter intimately associated specifically with uranium include "asphaltite" (Hawley et al., 1965), "urano-organic" (Haji-Vassiliou and Kerr, 1972, 1973; Curiale, 1983), "organo-uranium" (Haji-Vassiliou and Kerr, 1980), and "uraniferous hydrocarbons" (Parnell and Eakin, 1987).

The spatial or genetic relationships between uranium mineralization and migrated hydrocarbons have frequently been

noted. In one example, organic matter is the host of most of the uranium in the unoxidized or primary deposits of the Temple Mountain District, Utah (Hawley et al., 1965). They describe the organic matter as a "black, semi-lustrous to lustrous, rather hard uraniferous substance having a semiconchoidal fracture" which is found as nodules of various sizes, as interstitial fillings, and as massive replacements along bedding planes and the contacts of ore rolls. Urano-organic matter is associated with sulphide mineralisation at La Bajada, New Mexico, and occurs as spherical inclusions or filling cavities and fractures (Haji-Vassiliou and Kerr, 1972). It is a black, lustrous and breaks with a subchoncoidal to conchoidal fracture in hand specimen and is only slightly soluble in carbon disulphide (Haji-Vassiliou and Kerr, 1972). Dispersed urano-organic nodules which have uranium distributed fairly uniformly in them and occur in siltstones are described by Curiale et al. (1983). Hawley et al. (1965) describe the uraniferous asphaltite as commonly opaque but may in part be translucent (reddish-brown) and in polished section under cross-polars display distinctive mottling which is most intense around blebs of uraninite. Thucholite from the Witwatersrand system displays a marked increase in anisotropism, mottling and reflection pleochroism adjacent to uraninite grains (Liebenberg, 1955). Thucholite, described from the Isle of Man by Davidson and Bowie (1951), also displays similar petrographic characteristics. Thucholites which generally show an increase in reflectance and, more rarely, a decrease of fluorescence towards their centers, are present in sedimentary rocks of Precambrian to Mesozoic age and are more

generally recognised by the accreted nature of the organic matter around their mineral core (Cook and Kantsler, 1982).

4.4 Kerogen

The term "kerogen" was first introduced by Crum-Brown in 1912 to denote specifically the organic matter in oil shale which, on heating and decomposition, gives rise to shale oil (Cane, 1976). It is now usually defined as being any organic material found in carbonaceous (non-coal) rocks which is insoluble in common organic solvents (Tissot and Welte, 1978). Most global classification schemes do not include this term except for Wen et al. (1978) who consider, erroneously, that kerogens are fusible.

Kerogen can be characterised geochemically by plotting its atomic ratio H/C against its atomic ratio O/C on what has been called a "van Krevelen diagram" by Tissot and Welte (1978) after van Krevelen (1961) who first used it to characterise coals and their coalification paths. Tissot et al. (1974) found that kerogen from shales from different localities and ages in the Phanerozoic formed three major evolution paths on a van Krevelen diagram which they called paths I, II and III, in a manner similar to the coalification paths of the major coal maceral groups as observed by van Krevelen (1961). Tissot and Welte (1978) refer to kerogen that plot on paths I, II and III as Type I, II or III, respectively. They describe Type I kerogen as having a high initial H/C atomic ratio (ca. 1.5 or more) and a low initial O/C atomic ratio (generally smaller than 0.1), Type II kerogen as having a relatively high H/C and low O/C ratio, and Type III kerogen as having a relatively low initial H/C and a

high O/C atomic ratio (as high as 0.2 or 0.3). In addition to these three types, Tissot and Welte (1984) include a *residual type* which is characterised by abnormally low H/C ratios associated with high O/C ratios.

Cooles et al. (1986) divide kerogen into three parts based on its initial breakdown products: (1) labile kerogen which breaks down to form oil, (2) refractory kerogen which forms gas and (3) inert kerogen which "yields neither oil nor gas but eliminates hydrogen, oxygen, sulphur and nitrogen so as to achieve the most stable form of carbon - graphite". They also refer to labile kerogen and refractory kerogen collectively as reactive kerogen.

4.5 Coal and Oil Shales

Coal and oil shales are obviously of considerable economic importance and the organic matter in them has received a large amount of attention. Particularly relevant to this study is the nomenclature that has been developed which is based on petrographic criteria. The microscopic study of thin sections of coals commenced in the latter half of the nineteenth century but the practice of examining polished surfaces with oil-immersion objectives using reflected light, a method which gave less glare, did not become common until the 1930's (Stach et al, 1982). The use of fluorescence microscope techniques became common practice following its introduction for source rock studies by Jacob (1961) although the observation that irradiation with short-wavelength light causes fluorescence of some of liptinites had been known for some time (Teichmuller,

1986). Its use has particularly facilitated the optical resolution of organic components in oil shales (Sherwood and Cook, 1984).

Coal contains a variety of microscopically discernable organic entities called macerals, a term introduced by Stopes (1935), whose definitions have been formalized by the International Committee for Coal Petrology (ICCP) and published in a handbook which is updated from time to time with supplements (*International Handbook for Coal Petrography* published by the ICCP; 1963, 1971, 1975). According to the definition in the handbook "a maceral is a microscopically recognizable individual constituent which does not contain any mineral substances resolvable with the microscope". Since the last edition of the handbook (1963) and supplements (1971,1975) some new maceral terms have been proposed which are relevant to this study. Hutton et al. (1980), Cook et al. (1981), and Hutton (1982) undertook systematic studies of Phanerozoic oil shales, and defined two submacerals of alginite originally called alginite A and alginite B by Hutton et al. (1980) but renamed telalginite and lamalginite by Cook et al. (1982). Hutton (1987) states that the ICCP nomenclature system is suitable for describing organic matter in oil shales provided the terminology of organic matter derived from algal precursors is divided into these two submacerals.

4.6 Classification of Precambrian Organic Matter

Although major coal deposits did not form until after the first land plants had evolved during the Devonian, 370 m.y. ago (Stach et al., 1982), rocks containing significant amounts of carbonaceous matter are known from the Archaean

(McKirdy, 1974) and some apparently contain sufficient organic matter in them to be classified as coal. The oldest known coal (anthracitic in rank) occurs in the Middle Huronian (ca. 2300 m.y.) in Michigan and contains probable algal structures (Stach et al., 1982). Anthracitic layers also occur in upper Huronian sediments in Michigan as lenticular bodies concordantly bedded in black pyritic shales and are considered by Tyler et al. (1957) to be derived from algal remains. Other coals (meta-coal, anthracite, shungite) which have been reported from the Proterozoic include those from the Soviet Karelia which are about 1800 to 1900 m.y. old (Cloud, 1972) and from the Koolpin Formation (1880 Ma, Page et al., 1984) in the Pine Creek Geosyncline of northern Australia (Crick et al., 1980).

Only a few petrographic observations of Precambrian organic matter have been published and these observations come from the Australian Precambrian. In the Amadeus Basin, some of the particulate organic matter in rocks from the Late Proterozoic have been described as "vitrinite-like" commonly having a micro-coke texture as a result of fusinitization and a variable reflectivity ranging from a mean R_{0max} of 1.40% to 3.20% suggesting a rank equivalent to semi-anthracite (A. Kantsler, pers. comm. in McKirdy, 1977). Thucholites having mean R_{0max} values of between 1.7 - 1.8% and low reflectivity "algal balls" were also observed in one specimen (Kantsler, op. cit.).

Alginite, forming stringers up to 100 microns long but more commonly 20-30 microns long, which locally coalesce to form structureless complex agglomerations (mean R_{0max} ~0.15%) and thucholite, forming spheres about 10-50 microns in diameter,

have been reported from Middle Proterozoic shales of the McMinn Formation in the Roper Group of the McArthur Basin (A. Kantsler, pers. comm. in McKirdy, 1977, and pers. comm. in Peat et al., 1978). A photomicrograph of this alginite is shown by Hutton et al. (1980) who call it "alginite B". The degree of coalification of the kerogen in the McMinn Formation increases towards a dolerite sill from a rank equivalent to low volatile bituminous coal to that of anthracite (McKirdy, 1977). McKirdy et al. (1984) calls this organic matter "vitrinite-like material" and notes that its reflectance reaches a maximum of 2.7% near the dolerite sill.

4.7 Conclusions

A large number of terms, used to describe organic matter in Phanerozoic rocks, are clearly unsuited for this study as they contain no petrographic criteria in their definitions. The term "bitumen", for example, cannot be used if its definition is based solely on the chemical criteria given by some authors. However it could justifiably be used if its definition is based on the petrographic criteria given by Jacob (1976, 1981).

The approach adopted in this study is not to ignore terms used to petrographically describe Phanerozoic organic matter, but to apply them if warranted.

CHAPTER 5

NOMENCLATURE AND PETROGRAPHIC DESCRIPTIONS OF THE ORGANIC MATTER IN PROTEROZOIC SEDIMENTARY ROCKS OF THE McARTHUR BASIN

5.1 Introduction

Organic matter in Proterozoic sedimentary rocks of the McArthur Basin can mostly be petrographically characterised by using existing descriptions, derived from Phanerozoic studies, as "lamalginite", "bitumen" and "thucholite". However, a new organic matter type, "oncalginite", is informally defined here from the McMinn Formation of the Roper Group. The origins of these organic matter types are discussed in Chapter 10.

5.2 Nomenclature and Definitions

5.2.1 *Lamalginite*

Lamalginite in Phanerozoic sediments is defined by Hutton et al. (1980) as finely-banded lamellar alginite intimately interbedded with mineral matter and composed of single isolated films, or aggregations of films that form thicker strands. It has a weak to strong fluorescence with fluorescence colours varying from green through yellow and orange to brown. It commonly "binds" mineral matter where it resembles an algal mat and the individual films or lamellae are typically around 0.001 mm to 0.002 mm but generally less than 0.005 mm thick and 0.05 mm to 1.5 mm in length (Cook and Kantsler, 1982).

In this study the term lamalginite extends to organic matter that is nonfluorescing, and has a similar morphological appearance to fluorescing lamalginite. The informal term "nonfluorescent lamalginite" is applied to this organic matter. Individual lamellae within larger strands of nonfluorescent lamalginite are not recognizable.

5.2.2 *Oncalginite (new name)*

Organic matter that forms thin, commonly concentric bands, in oncolites is here called oncalginite. It differs from lamalginite in that the orientation of the organic matter is not along the bedding plane but is controlled by the morphology of the oncolite. An oncolite is defined by Gary et al. (1974) as "a small variously shaped (often spheroidal), concentrically laminated, calcareous sedimentary structure, resembling an oolith, and formed by the accretion of successive layered masses of gelatinous sheaths of blue-green algae. It is smaller than a stromatolite and generally does not exceed 10 cm in diameter." Monty (1976) simply refers to oncolites as "unattached subspherical, ovoid, lobate or flattened structures otherwise similar to stromatolites" and Walter (1976) defines an oncolite as a "unattached stromatolite with encapsulating laminae".

A more precise definition for oncalginite is not possible here as only one polished block containing a 5 cm thick bed of oncolites from the McMinn Formation in the Roper Group, (DDH Urapunga 4, 32.3 m) was examined. The oncolites in this bed are spherical, elliptical or irregularly shaped bodies up to 3 mm in diameter, commonly having nucleii made of a grain or several

grains of minerals, mostly quartz, and surrounded by concentric layers of lighter mineral and darker organic matter (Plate 32). The oncalginite is generally uniformly thin (less than 5 microns thick), but can reach up to about 15 microns in thickness (Plate 33). It is nonfluorescent, has a silvery appearance under reflected white light and forms single or multiple concentric bands within the oncolites.

Oncalginite clearly formed under different circumstances to the other types of organic matter described here from the McArthur Basin and has not been described elsewhere from Phanerozoic or other Precambrian sedimentary rocks.

5.2.3 Bitumen

The term "bitumen" is used here according to the definition of Jacob (1976, 1981) who considers that the most important characteristic for distinguishing solid bitumens from coal under the microscope is "in general their passive behaviour with respect to their form" i.e. the variety of morphological form.

The types of bitumen present in the McArthur Basin have here been mostly informally classified as: (1) *Patchy dispersed bitumen*, (Plates 6e,f; 25a; 26e,f; 27c,f; 28g,h) comprising loose aggregates of irregularly shaped grains whose margins are commonly defined by crystal faces of the mineral matrix and are generally less than 10 microns in size, as distinct from (2) *disseminated bitumen* (Plates 7b,c,d; 9a-f; 25a; 26e-h; 27c,f; 36C,D,F,G) made up of generally similarly sized and shaped bitumen grains but occurring as isolated grains and not in patches; (3) *bitumen microspheres* (Plate 26e,f) which are

spherical bitumen structures less than 10 microns in diameter; (4) *cauliflower bitumen* (a term first used by McKirdy and Kantsler, 1980) which forms isolated cauliflower shapes up to 70 microns across (Plate 30a,b,c,f); (5) *matrix bitumen* (Plates 9e,f; 25e,f, 28i) which forms generally larger irregularly shaped masses, completely enveloping mineral grains; (6) *vein bitumen* (Plates 7a,e,g,h; 24d-i; 25h,i; 28d,e; 29; 31a,b) which runs parallel with or across bedding and in places form anastomosing veins and (7) *vug bitumen* (Plates 25g; 40E,F) which appears to occupy preformed spaces within the rock fabric.

5.2.4 Thucholite

Grains of organic matter formed around presumed or identified radioactive minerals, generally having a rounded shape and showing increased reflectivity towards the centre, have been classified as "thucholite" (Plates 8 and 38).

5.3 Organic matter in sedimentary rocks of the McArthur Basin

The amount of organic matter present in the lutaceous formations in the McArthur Basin varies from less than 1% to over 5% total organic carbon whereas, as would be expected, the mainly arenaceous units contained less than 1% total organic carbon (Figures 5-1,2). Lamalginite and bitumen are the most common types of organic matter whereas thucholite is less common and oncalginite has been observed in only one drill-core specimen (Table 5-1).

Figure 5-1. Histograms showing total organic carbon contents for some formations in the Nathan and McArthur Groups.

Figure 5-2. Histograms showing total organic carbon contents for formations of the Roper Group.

FORMATION/DDH	Lamalginitite		Bitumen							Th	Onc
	FL	NL	PDB	DB	MB	VB	VG	BM	CB		
ROPER GROUP											
McMinn Formation	X	X	X		X					X	X
Velkerri Formation	X	X	X	X	X	X		X	X	X	
Cobanbirini Formation											
"Cat Creek Member"	X	X								X	
"Lansen Creek Shale"	X	X	X	X		X		X		X	
Bessie Creek Sandstone		X	X								
Corcoran Formation		X	X	X							
Abner Sandstone		X		X		X					
Crawford Formation		X								X	
Mainoru Formation		X	X	X	X	X				X	
"Mantungula Formation"		X									
NATHAN GROUP											
Balbarini Dolomite		X	X	X							
McARTHUR GROUP											
Looking Glass Fmt.						X	X				
Yalco Formation	X	X			X	X				X	
Lynott Formation	X	X	X	X	X					X	
Reward Dolomite			X	X		X	X			X	
Barney Creek Fmt.	X	X	X	X	X	X				X	
Teena Dolomite		X	X			X				X	
Emmerugga Dolomite				X		X	X				

Table 5-1. Organic matter types identified in some formations within the McArthur Basin. (FL = fluorescent lamalginitite, NL = nonfluorescent lamalginitite, PDB = patchy dispersed bitumen, DB = disseminated bitumen, MB = matrix bitumen, VB = vein bitumen, BM = bitumen microspheres, VG = vug bitumen, CB = cauliflower bitumen, Th = thucholite, Onc = oncalginitite)

5.3.1 *McArthur Group*

Emmerugga Dolomite

Crosscutting and anastomosing bitumen veins, in places containing fine disseminated pyrite are present in the two samples examined from this formation. The bitumen also appears in places to have replaced carbonate rhombs or filled voids formerly occupied by them (Plate 25h).

Teena Dolomite

The organic matter types identified from the three samples examined from this formation are nonfluorescent lamalginite, vein bitumen (Plate 25i), patchy dispersed bitumen and thucholite. The vein bitumen in places contains pyrite and sphalerite.

Barney Creek Formation

A. Southern Batten Trough (Glyde River Subbasin)

The organic matter types identified in the Barney Creek Formation from this subbasin are:

(1) Lamalginite (Plates 3-6, 17)

Fluorescent lamalginite is generally abundant within lutaceous sediments in this subbasin. It consists, in sections perpendicular to bedding, of filamentous-looking organic matter with the filaments elongate parallel to bedding, varying in size from several microns to hundreds of microns long by less than 2 microns wide. The individual filaments (lamellae) are commonly grouped together to form thicker strands or thin

lenticular bodies or mats that are generally less than 0.5 mm long by 0.05 mm thick but, more rarely, up to lengths of several millimetres by 1 mm thick. In one case, they form apparently continuous mats (Plate 17). In one example, fluorescent lamalginite has been deformed by soft-sediment compaction around a large grain (Plate 4e).

Sections of fluorescent lamalginite parallel to bedding show an irregular but commonly roughly circular shape (Plate 4d,h). SEM examination of macerates showed the mats are made up of a number of thin flat layers which are the individual lamellae (Plate 10e,f).

Detrital or diagenetic mineral matter, commonly euhedral to subhedral carbonate, commonly occurs within the mats and in places the lamellae are deformed around them. In one example, a large mat appears to have relatively more carbonate in it than the surrounding sediments (Plate 16d). Lamalginite itself does not contain appreciable amounts of elements with atomic weights heavier than carbon (Plates 15,16). In one exceptional sample, a nodule and lenses of calcium phosphate occur within a large mass of lamalginite (Plates 17-20). The phosphate has clearly formed soon after deposition of the organic matter as the lenses have in one place been scoured (Plate 17,1). Individual lamalginite lamellae, containing inclusions of quartz, pyrite and probably clay minerals (Plate 20i-l), have apparently been detached by the formation of the phosphate in one of the lenses. Disseminated fine-grained euhedral pyrite is common throughout most of the Barney Creek Formation in the subbasin. No pyrite framboids were observed although in one rare example, an

aggregation of fine-grained pyrite is possibly pseudomorphous after a discoidal gypsum crystal (Plate 4f).

The fluorescence of the lamalginite varies from bright yellow to a dull brownish orange. There is an obvious decrease in fluorescence intensity and increase in its reddishness with depth. Figure 5-3 shows the intensity of fluorescence (I), as measured at 546 nm, decreases with depth in DDH GR10 and the red/green quotient (Q) shows a slight increase with depth indicating a shift towards the red end of the spectrum of the fluorescence. At depths greater than about 600 m, the lamalginite is not fluorescent.

The intensity of fluorescence of lamalginite generally changes when exposed to ultraviolet light irradiation for a period of time (Plate 9i). Figure 5-4 shows that after 30 minutes

Figure 5-3. Measurements of fluorescence intensity (I) at 546 nm and the red/green quotient " Q " (650/500 nm), plotted against depth, for lamalginite in the Barney Creek Formation, DDH GR10, Glyde River Subbasin. Mean value is the vertical line, 95% confidence limits of the mean is the solid bar, range of readings is the horizontal line and number of readings is represented by the numerals in brackets.

Figure 5-4. Alteration of fluorescence intensity at 546nm of lamalginite (Ai) from DDH GR10, Barney Creek Formation, after 30 minutes of irradiation.

of irradiation, lamalginite from the Barney Creek in DDH GR10 altered, with the exception of two examples, either positively (Plate 9i) or negatively. It is likely that all alteration is positive and that negative alteration is due to experimental error.

Nonfluorescent lamalginite occurs at depths greater than about 200 m in the subbasin. It commonly appears more deformed and disjointed in morphology than fluorescent lamalginite.

(2) Bitumen.

Patchy dispersed bitumen and disseminated bitumen occur at depths greater than about 200 m in the subbasin and are commonly associated with low fluorescing or nonfluorescing lamalginite (Plates 6,7). Vein bitumen is also present from depths greater than about 300 m (Plate 7).

Titaniferous bitumen nodules ranging in size from about 50 to 200 microns across, occur in drill-core from DDH GR10 at 37.4 m (Plates 11, 13 and 14). within a 2 cm band of greenish-grey claystone. Electron probe analyses of the nodules revealed the presence of the titanium as well as pyrite. The pyrite in one nodule has possibly replaced a piece of filamentous and branching algae trapped within the nodule (Plate 11). Larger nodules are probably composed of coalesced smaller nodules as X-ray mapping of one of the larger nodules for sulphur and iron shows these two elements surrounding what appears to be smaller nodules (Plate 14). A pyrite nodule having a spongy appearance and containing bright-yellow fluorescing inclusions of oil also occurs within this tuffaceous band (Plate 12). Titaniferous bitumen nodules and spongy pyrite nodules containing oil inclusions have not been observed elsewhere in the McArthur Basin.

Figure 5-5. Histogram of diameters of thucholite grains from DDH GR10, Barney Creek Formation.

(3) Thucholite

In hand-specimens, thucholite appears as black, commonly round, grains up to about 0.5 mm in diameter. Most thucholite grains in DDH GR10 have a maximum diameter of less than 50 microns (Figure 5-5). In polished blocks, thucholite grains have a silvery surface, like bitumen, and commonly have a noticeably higher reflecting central area and, in some cases, a reddish-brown to orange fluorescent halo.

The thucholitic bitumen is unaffected by the organic solvents toluene and chloroform. A polished block from 238.8 m in DDH GR10, which contained a number of thucholite grains, was immersed in toluene at room temperature for a total of 18 hours and in chloroform for a further 6 hours. Microscopic examination of the block and comparisons of photomicrographs taken before and after each session of immersion showed no apparent change to the polished surfaces or dimensions of the thucholites.

Mineral matter is contained in the larger thucholites in their central area either as a single grain or a number of scattered grains. The absence of mineral matter from the smaller thucholites is probably due to the polished section not passing through the centre of the thucholite.

Electron probe analyses and X-ray mapping of selected thucholite grains showed the central mineral matter is composed of thorium and silica and is therefore probably thorite (ThSiO_4) and that the thucholitic bitumen contains appreciable sulphur (Appendix E and Plates 21, 22).

(4) Oil inclusions and matrix oil

Oil inclusions commonly occur within carbonate grains as small (generally less than 3 microns), brightly fluorescing objects, and in many cases contain a gas bubble which is constantly moving (Brownian movement) (Plate 9g). In some cases the oil inclusions do not appear to have a gas bubble, are rhombic in shape, and appear to occupy spaces caused by lattice defects within some carbonate grains. Larger oil inclusions occur in one specimen in which the oil may be filling a vug (Plate 7i).

Mineral fluorescence is ubiquitous and varies from bright yellow-green to dull orange. Fluorescence intensities and colour can show great variation within one sample and even within one mineral grain. Some carbonate rhombs show a distinct fluorescence zonation. Overall, there is a lessening of fluorescence intensities with depth and a shift in colour towards the red end of the spectrum .

Much of the mineral fluorescence seen in specimens from this subbasin is probably due to the adsorption of liquid hydrocarbons or their inclusion into carbonates formed in the presence of liquid hydrocarbons. As a check, a drop of oil, extracted from the Velkerri Formation in the Roper Group, was placed on a block of non-fluorescing greywacke from eastern Australia (Lachlan Fold Belt) and irradiated with ultraviolet light. The greywacke fluoresced in a very similar manner to the mineral fluorescence commonly observed in the Glyde River Subbasin (Plate 35G).

B. Central and northern Batten Trough

Organic matter in the Barney Creek Formation from this region is composed of nonfluorescent lamalginite, patchy dispersed bitumen, disseminated bitumen, matrix bitumen, vein bitumen and thucholite (Plate 25). No fluorescent lamalginite was observed and mineral fluorescence is weak to absent.

Reward Dolomite

Organic matter types identified in this formation are patchy dispersed bitumen, dispersed bitumen, vein bitumen and thucholite. Mineral fluorescence is weak to absent.

Lynott Formation

The Lynott Formation contains fluorescent and nonfluorescent lamalginite, patchy dispersed bitumen, disseminated bitumen, vein bitumen and thucholite. Fluorescent lamalginite occurred in one specimen (DDH 82/6, 290.3m) as thin, low fluorescing, strands up to 100 microns long by 1 to 3 microns in width. Mineral fluorescence is weak to absent.

Yalco Formation

Fluorescent and nonfluorescent lamalginite, matrix bitumen, vein bitumen and thucholite are present in this formation. The fluorescent lamalginite consists of thin (less than 3 microns wide) wavy strands, commonly in excess of 200 microns long, and in places have been disrupted by sandstone dykes (Plate 24a) or are in low-angle cross-beds (Plate 24b).

Looking Glass Formation

Abundant vein and vug bitumen was present in the one specimen examined from this formation.

5.3.2 Nathan Group

Balbarini Dolomite

Nonfluorescent lamalginite, patchy dispersed and disseminated bitumen occur in the two specimens examined from this formation.

5.3.3 Roper Group

Mainoru Formation

Nonfluorescent lamalginite up to 600 microns long by less than 5 microns wide, but commonly less than 100 microns long by 5 microns wide, are present as discrete bodies. In one example the lamalginite is composed of two parallel thin strands (Plate 39H). Patchy dispersed, disseminated, matrix and vein bitumen, and thucholite, are also present within the lutites of this formation (Plates 27g-i; 39G-I and 40A,E-H).

Crawford Formation

Nonfluorescent lamalginite, forming discrete bodies up to 200 microns long by 5 microns wide, occurs in the one example examined from this formation.

Abner Sandstone

Discrete bodies of nonfluorescent lamalginite up to 200 microns by 5 microns are contained within the pelitic units of this formation (Jalboi and Arnold Members) (Plates 39F, 40B-D). Vein and disseminated bitumen are also present

Corcoran Formation

Nonfluorescent lamalginite forming thin discrete strands up to 5 mm long, in places showing soft-sediment deformation, together with patchy dispersed bitumen and disseminated bitumen occur in silty beds within this organically-poor unit (Plates 27e and 36E-G).

Bessie Creek Sandstone

Nonfluorescent lamalginite up to 50 microns long, patchy dispersed bitumen and disseminated bitumen occur in the one specimen observed from this formation (Plate 27a-d).

Cobanbirini Formation

Cat Creek Member

Discrete strands of fluorescent and nonfluorescent lamalginite up to 200 microns long by 10 microns wide, and thucholite were present in the one specimen examined. Fluorescence of the lamalginite varies from a dull orange to faint brownish-orange.

Lansen Creek Shale Member

Fluorescent and nonfluorescent strands of lamalginite up to 500 microns long, patchy dispersed and disseminated bitumen, vein bitumen and thucholite occur in this formation (Plate 26). Fluorescence of the lamalginite varies from dull yellow to faint brownish-orange. In rare examples, the fluorescence of a single strand of lamalginite varies from dull yellow to being absent altogether (Plate 26b). In one sample, bitumen microspheres, less than 10 microns diameter, are associated with similarly-sized microspheres of calcium phosphate (Plates 26e and f; 42G-I).

Velkerri Formation

Fluorescent and nonfluorescent lamalginite, patchy dispersed bitumen, disseminated bitumen, matrix bitumen, bitumen balls, cauliflower bitumen, vein bitumen and thucholite are present in this formation. Fluorescent lamalginite forms strands up to 300 microns long and its fluorescence varies from yellow to a faint orange-brown (Plates 28b,c; 34A-F). Nonfluorescent lamalginite is, in places, deformed and poorly orientated by soft-sediment slumping (Plates 31 c-g, 35A). Bitumen microspheres, less than 10 microns in diameter, associated with similarly-sized calcium phosphate microspheres, which, in some cases, are within strands of nonfluorescent lamalginite, are present in places (Plates 30d; 34G; 42A-F). The phosphate microspheres display, in some cases, a fluorescent outer shell (Plate 34H).

Liquid hydrocarbons, which bubbled from core from DDH Urapunga 4 between 345.4 and 345.55 m (Jackson et al, 1986) is also present within vugs and fissures at 342.7 m (Plate 35E,F,H).

McMinn Formation

Fluorescent lamalginite, nonfluorescent lamalginite, oncalginite, patchy disseminated bitumen, matrix bitumen, vein bitumen and thucholite are present in this formation. Fluorescence of the lamalginite ranges from strong yellow to weak orange-brown. The fluorescent lamalginite varies in size from thin filamentous-like structures less than 10 microns long by 1 micron wide to long, wavy strands exceeding 2 mm in length by up to 50 microns thick (Plate 37).

CHAPTER 6

REFLECTANCES OF THE ORGANIC MATTER TYPES

6.1 Introduction

Reflectance measurements were made on lamalginite and bitumen in the McArthur and Nathan Groups (Appendix F) and Roper Group (Appendix G). Thucholite reflectances were measured in samples from the Barney Creek Formation in the Glyde River subbasin where there are sufficient numbers of thucholite occurrences to allow such a study to be made (Appendix F)

6.2 Reflectances of Lamalginite and Bitumen

6.2.1 *Lamalginite*

The least mature specimens of fluorescent lamalginite display translucent pale reddish-brown reflective surfaces and low reflectances of less than 0.20%. At higher reflectances these surfaces have a grey colour. Nonfluorescent lamalginite has a silvery surface and is noticeably anisotropic.

The presence of a radioactive mineral adjacent to fluorescent lamalginite produces a noticeable halo of increased reflectance and decreased fluorescence (Plate 8e,f). Care had to be exercised in measuring the reflectance of the lamalginite, particularly nonfluorescent lamalginite, to ensure that measurements were not made of surfaces affected by radioactivity.

Nonfluorescent lamalginite occurs with fluorescent lamalginite in some specimens (Plates 26a,b; 28b,c; 34E,F). In these

cases, the fluorescent lamalginite have mean maximum reflectances in excess of 0.20% and the nonfluorescent lamalginite have reflectances of about twice that of the fluorescent lamalginite (Figure 6-1; Appendix H). There is, in some cases, an overlap in the range of reflectances of both types which may be attributed, at least in part, to the difficulty in deciding whether a piece of lamalginite is fluorescing or not. At very low levels of fluorescence, the decision is largely influenced by the operator's own acuity of eye and the intensity and wavelengths of the incident light.

Figure 6-1. Mean maximum reflectances (mean maxRo%) for fluorescent and nonfluorescent lamalginite from the same specimens, Roper and McArthur Groups

6.2.2 Bitumen

Bitumen, under plane-polarised reflected light, has a silvery appearance and is commonly optically non-homogeneous but contains zones or areas of homogenous material (e.g. Plates 24d,e, and 29). Care had to be taken in measuring its reflectance to ensure that the measuring field was kept placed over an homogenous area.

Figure 6-2. Histogram of mean maximum reflectances for the various organic matter types (excluding thucholite) in the McArthur Basin.

Figure 6-3. Histogram of mean maximum reflectances in the range 0.0 - 1.59% for various organic matter types (excluding thucholite) in the McArthur Basin.

Reflectance measurements on organic matter in polished blocks containing mixed maceral populations, including bitumen, show that there are no obvious differences in reflectances between the various forms of bitumen, or between these forms and nonfluorescent lamalginite (Appendix I). Reflectance measurements on samples with mixed maceral assemblages containing different forms of bitumen, with or without nonfluorescent lamalginite, are therefore grouped together for statistical purposes.

6.2.3 *Ranges of Mean Maximum Reflectances*

The range of mean maximum reflectances for the various organic matter types, excluding thucholites, are shown in Figures 6-2, 3. In detail, the ranges observed are:

- 1) fluorescent lamalginite, 0.05 - 0.53%;
- 2) nonfluorescent lamalginite, 0.42 - 4.27%;
- 3) patchy dispersed bitumen, 0.68 - 2.76%;
- 4) disseminated bitumen, 0.93 - 5.39%;
- 5) vein bitumen, 0.79 - 5.34, and
- 6) matrix bitumen, 0.44 - 2.77%.

6.2.4 *Relationships between Mean Maximum and Mean Minimum Reflectances*

There is a clear relationship between mean maximum and mean minimum reflectances for these organic matter types. The relationship is best expressed as a logarithmic equation overall (Figure 6-4) but for mean maximum reflectances below 1.6%, it is best expressed as a simple linear equation (Figure 6-5).

Figure 6-4. Relationship between maximum and minimum mean reflectances for all organic matter types, excluding thucholites, but including means of mixed maceral populations.

Figure 6-5. Relationship between maximum and minimum mean reflectances up to a maximum mean reflectivity of 1.5% for all organic matter types, excluding thucholites, but including means of mixed maceral populations.

Figure 6-6. Relationship between maximum and maximum minus minimum mean reflectances for all organic matter types, excluding thucholites, but including means of mixed maceral populations.

Figure 6-7. Relationship between maximum and minimum mean reflectances for all organic matter types, excluding thucholite, including means of mixed maceral populations, as for Figure 6-4, and showing vitrinite trend lines and semi-graphite range derived from Stach et al. (1982) and A. C. Cook (pers. comm.)

All organic matter examined in the McArthur Basin is optically anisotropic which at low levels of reflectance is not marked but at higher reflectances is quite marked (Figure 6-6).

The relationship between maximum and minimum mean reflectances of the McArthur Basin organic matter above about 1.0% mean maximum reflectance is similar to that of vitrinite (Figure 6-7).

6.3 Reflectances of Thucholite

Large thucholites clearly show an increase in reflectance towards their center whereas in smaller thucholites the change in reflectance is commonly not obvious. Reflectance measurements made across large thucholites (>50 microns) from DDH GR10 in the Barney Creek Formation commonly show an exponential increase in reflectance towards the center (Appendix J). The smaller thucholites (<50 microns) are more irregular in their reflectance patterns, but generally also show increasing reflectances towards their central areas.

Figure 6-8. Relationship between maximum and minimum mean reflectances for thucholites from DDH GR10. Reflectance measurements made at 1micron in from the edges.

Figure 6-9. Relationship between maximum and minimum mean reflectances for all organic matter types, including thucholite, and also means of mixed maceral populations.

Figure 6-10. Relationship between maximum minus minimum mean reflectances versus mean maximum reflectances for thucholites from DDH GR10. Reflectance measurements made at 1micron in from the edges.

Mean minimum reflectances of thucholitic bitumen are clearly less than the mean maximum reflectances (Figure 6-8) and are of the same order as for other types of organic matter in the McArthur

Basin (Figure 6-9) Its optical anisotropy increases with increasing mean maximum reflectance (Figure 6-10).

6.4 Changes to Reflectances with Increasing Depth

With some exceptions, the reflectances of lamalginite and bitumen significantly increase with increasing depth in individual drill holes clearly demonstrating that the maturation processes resulting in the commonly observed increases in reflectances with depth of Phanerozoic organic matter are producing similar results in this Precambrian organic matter (discussed in more detail in Chapter 8).

Increases in reflectances with increasing depth for thucholites of all sizes or for thucholites having maximum diameters of less than 50 microns is less clear (Figure 6-11; Appendix F). The reflectance measurements were made on thucholites from DDH GR10 and taken one micron in from well-defined edges of the thucholites in an attempt to assess whether external maturation processes may have produced any changes. Such processes could conceivably superimpose over the effects produced by radiation with the greatest effect being produced closest to the edges. Thucholites of less than 50 microns in diameter are sections through much larger thucholites in many cases, and measurements taken one micron in from their edges are more likely to be closer to the edge than measurements made at the same distance in from the edge in larger thucholites.

Reflectances of thucholites of all sizes generally show a slight increase with increasing depth (Figure 6-11A). Surprisingly, the increase in reflectances of thucholites, less than 50 microns in

Figure 6-11. Mean maximum reflectance values (mean maxRo%) showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), versus depth for thucholites of all sizes (A) and for thucholites whose maximum sizes are less than 50μ (B) from DDH GR10 in the Barney Creek Formation, Glyde River Subbasin.

Figure 6-12. Maximum reflectances (maxRo%) of lamalginite and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes) versus depth for DDH GR10, Barney Creek Formation, McArthur Group.

diameter, with increasing depth is less clear. Reflectances from these smaller thucholites are generally lower, as expected. However, absorption of incident light by the underlying mineral matrix in extremely thin sections of thucholites may have contributed to the lower reflectances and, to some extent, masked any increases in reflectances. Reflectances of fluorescent lamalginite, nonfluorescent lamalginite and/or bitumen show a more sharply defined increase with increasing depth in the same drill hole (Figure 6-12).

CHAPTER 7

ASSESSMENT OF MATURATION LEVELS

7.1 Introduction

Indices which are used to determine maturation levels of organic matter in Phanerozoic sedimentary rocks may behave quite differently in these Precambrian rocks given the enormous amount of time between deposition and the present day, and the primitiveness of the source biota.

The approach adopted in this chapter is to compare three maturation indices (Tmax, reflectances, and calculated vitrinite reflectances derived from methylphenanthrene indices (MPI)) with published results from the Phanerozoic and with the "oil-window" for McArthur Basin rocks. The use of MPI data provides an independent means for calibrating the various indices.

7.2 Tmax

The maturation index, Tmax, derived from Rock-Eval analyses, represents the temperature of maximum evolution of hydrocarbons during pyrolysis (Espitalie et al., 1977). Tmax is affected by the type of organic matter in the source-rock such that the range in variation of Tmax is narrower for Type I kerogen (435-450°C) than for Type II (420-460°C) or Type III kerogens (400-600°C) (Espitalie et al., 1986) due to the differing bond energy spectrums of the different organic matter types (Tissot et al., 1987a).

Figure 7-1. Van Krevelen diagram showing differences in the atomic H/C and O/C ratios of kerogen in selected samples.

A plot of H/C versus O/C (a van Krevelen diagram (Tissot and Welte, 1978)) for elemental analyses of kerogen from the McArthur Basin (Figure7-1; Appendix Q) show that some of the kerogen samples from the Barney Creek Formation can be clearly classified as Type I kerogen whereas most of the kerogen is Type II, Type II/III or Type III. The clearest examples of Type I organic matter in Figure 7-1 come from within the top 300 m of DDH GR10 in the Glyde River Subbasin.

Tmax measurements are unreliable in samples of low pyrolysis yields (<0.2 kg/tonne) and samples containing migrated hydrocarbons; the latter results in a suppression of Tmax values commonly due to the poor separation of the S1 and S2 peaks during analysis (Clementz, 1979). The presence of migrated hydrocarbons is indicated from the Production Index (PI) which is the ratio of S1 to S1 + S2 where S1 is the amount of free hydrocarbons released during pyrolysis (Espitalie et al., 1977) and can commonly be detected by the presence of positive anomalies in relation to the mean PI values (Espitalie et al., 1985). In the absence of any migrated hydrocarbon, production indices increase with increasing maturity as hydrocarbons are cracked from kerogen without going above about 0.5 for the oil-production zone (Espitalie et al., 1985).

Tmax values were obtained on all samples collected from the McArthur Basin (Appendix N) but a considerable number of them are unreliable because of low pyrolysis yields (<0.20 kg/tonne). PI values generally increase with depth as is the case for the Barney Creek in the Glyde River Subbasin (e.g. Figures 7-2, 4, and 6) and for the Velkerri Formation (Figures 7-8 and 7-10). Suppression of Tmax values related to relatively high PI values is clearly evident in the 90 -140 m zone in Urapunga 3 (Figure 7-8).

The mineral matrix affect which can result in raising Tmax values (Espitalie et al., 1980) is more difficult to assess. There do not appear to be any anomalously high Tmax values (where S2 $\geq$ 0.2) obviously due to this affect.

Tmax values which are selected as representative for the McArthur Basin are those where S2 is greater than 0.20 kg/tonne and there is no clear suppression of the Tmax values due to poor separation of the S1 and S2 peaks. These selected Tmax values generally show a systematic increase with depth, and range from 426 to 550°C for the McArthur Group and from 430 to 488°C for the Roper Group. Some Tmax values for the top of the Barney Creek Formation, McArthur Group, in the Glyde River Subbasin are less than 435°C which, if all the organic matter is Type I as is the case for the top of DDH GR10, suggests this organic matter is immature. The lowest Tmax value in the McArthur Group is 426°C and comes from the Yalco Formation. However, as the organic matter appears to be Type II then this value indicates that it is marginally mature. The majority of Tmax values in the McArthur Group are greater than 435°C indicating that the organic matter is mature to overmature. The Tmax values for the Roper Group suggest that the organic matter ranges from being mature to overmature if it is mostly Type II or Type III kerogen.

7.3 Reflectance

Reflectance values for organic matter in the McArthur Basin are given in Chapter 6. It is not possible to assess the maturation levels of lamalginite by comparison with Phanerozoic examples as no reflectance studies on Phanerozoic lamalginites have been published. However, if lamalginite has

Figure 7-2. T_{max} values and production indices (PI) versus depth for DDH GR7, Barney Creek Formation, McArthur Group.

Figure 7-3. Maximum reflectances ($maxRo\%$) of lamalginite and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), and reflectances calculated from MPI-1 indices (x) using equation 1 (Chapter 6), versus depth for DDH GR7, Barney Creek Formation, McArthur Group.

Figure 7-4. Tmax values and production indices (PI) versus depth for DDH GR10, Barney Creek Formation, McArthur Group. The symbols "+" are Tmax values where S2 is less than 0.2 kg/tonne.

Figure 7-5. Maximum reflectances (maxRo%) of lamalginites and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), and reflectances calculated from MPI-1 indices (x) using equation 1 (Chapter 6), versus depth for DDH GR10, Barney Creek Formation, McArthur Group.

Figure 7-6. Tmax values and production indices (PI) versus depth for DDH GR11, Barney Creek Formation, McArthur Group. The symbols "+" are Tmax values where S2 is less than 0.2 kg/tonne.

Figure 7-7. Maximum reflectances (maxRo%) of lamalginites and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), and reflectances calculated from MPI-1 indices (x) using equation 1 (Chapter 6), versus depth for DDH GR11, Barney Creek Formation, McArthur Group.

Figure 7-8. T_{max} values and production indices (PI) versus depth for DDH Urupunga 3, Velkerri Formation, Roper Group. The symbols "+" are T_{max} values where S2 is less than 0.2 kg/tonne.

Figure 7-9. Maximum reflectances (maxRo%) of lamalginite and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), and reflectances calculated from MPI-1 indices (x) using equation 1 (Chapter 6), versus depth for DDH Urupunga 3, Velkerri Formation, Roper Group.

Figure 7-10. T_{max} values and production indices (PI) versus depth for DDH Urupunga 4, McMinn Formation (0-42m), Velkerri Formation (42-372.5m) and Corcoran Formation (397.6-532m TD). The symbols "+" are T_{max} values where S2 is less than 0.2 kg/tonne.

Figure 7-11. Maximum reflectances ($maxRo\%$) of lamalginite and bitumen showing the range (horizontal line), mean (vertical line) and 95% confidence limits of the mean (black boxes), and reflectances calculated from MPI-1 indices (x) using equation 1 (Chapter 6), versus depth for DDH Urupunga 4.

similar reflectances for the same level of maturation as Phanerozoic sporinites then, using the data given in Smith and Cook (1980), lamalginite reflectances of between about 0.1 to 1.5% fall within the oil-window.

It is also not possible to reliably assess the maturation levels of bitumen in terms of its reflectances by comparison with the limited studies on Phanerozoic bitumens. Robert (1973) concentrated bitumen by a froth flotation technique from a number of sedimentary basins and measured random reflectances on the concentrates. His results mostly do not provide any clear indication of a relationship between bitumen reflectances and vitrinite reflectances due the problem of migrated bitumen but do indicate that for one group of non-migrated bitumen having a reflectance of about 2% that it is equivalent to a vitrinite reflectance also of 2%. Ogunyami et al. (1980) measured random reflectances on asphaltic pyrobitumens separated from the rock by HCl and HF treatment from early Palaeozoic continental margin deposits of the Quebec Appalachians and compared them to the level of illite crystallinity. No attempt was made to define bitumen reflectances in terms of vitrinite reflectances or other maturation indices other than to comment that bitumen having a reflectance of 1.0 to 1.5% may still be in the oil window.

7.4 Methylphenanthrene Index

The Methylphenanthrene Index (MPI-1), is one of a number molecular organic maturation indicators based on various ratios

of aromatic hydrocarbons and one that has a strong correlation with vitrinite reflectance (Radke et al., 1982a, b; Radke and Welte, 1983; Radke et al., 1984). There are progressive changes with maturation of the distribution of phenanthrene and four of the methylphenanthrene isomers used to define MPI-1 such that there is a systematic increase in the relative abundance of 2- and 3-methylphenanthrene over the 1- and 9- isomers. At higher temperatures, demethylation reactions lead to a lowering of the MPI-1 index. The MPI-1 index has been recalibrated against vitrinite reflectance using Australian Carboniferous, Permian, Jurassic and Tertiary sediments and coals (Boreham et al., 1988) where for vitrinite reflectance levels between 0.3% and about 1.7% the relationship is:

$$1) \text{ calculated vitrinite reflectance percentage (Rc\%)} = 0.7(\pm 0.05)(\text{MPI-1}) + 0.22;$$

where the standard error is expressed as (± 0.05) . At vitrinite reflectances greater than about 1.7% the relationship is:

$$2) \text{ calculated vitrinite reflectance percentage (Rc\%)} = -0.55(\text{MPI-1}) + 3.0.$$

At vitrinite reflectances between 0.3-1.7% the relationship has a significant correlation ($r = 0.84$, 91 samples) whereas at the higher vitrinite reflectance levels the relationship is less well-defined as it is based on only four samples due to the low yields of extractable hydrocarbons in the overmature zone (Boreham et al., 1988).

In the McArthur Basin, the MPI indices for selected samples is given in Appendix P. There is no apparent reversal of the MPI-1 indices in samples from which organic matter reflectances were obtained (Figure 7-12). Therefore, for calculating the

equivalent vitrinite reflectances for these samples equation 1 was used (Figure 7-13). However, a reversal of the MPI indices is noticeable in DDH Urapunga 3 at reflectances above about 2.0%. Equation 2 provides a better correlation to these reflectances (Figure 7-9) which were obtained on different samples to those used for the MPI-1 analyses and therefore have not been included in Figures 7-12 and 7-13.

As can be seen from Figure 7-13, the values for fluorescent lamalginite mostly fall within the limits of measured reflectances for Phanerozoic liptinite between the trend-lines for telalginite and lamalginite, whereas most of the other organic types are within the limits of measured reflectances for Phanerozoic vitrinites. The reflectance of fluorescent lamalginite is depressed by about 0.4 to 0.5% with respect to the calculated values for vitrinite, a displacement that is similar to that which would be predicted from the diagrams in Smith and Cook (1980) for plots of co-existing sporinite and vitrinites.

7.5 Tmax versus extractable hydrocarbon yields.

Selected core samples were analysed for extractable hydrocarbons (Appendix O) and the yield obtained is given as a percentage of the total organic carbon content (TOC). Most hydrocarbon yield values fall below 200 mg/g and between Tmax values of 425 to about 470°C (Figure 7-14). The Tmax values of some samples which are below 420°C are clearly suppressed due to migrated hydrocarbons and the two highest yields observed

Figure 7-12. Methylphenanthrene indices (MPI-1) versus the measured mean maximum reflectances (mean maxRo%) of organic matter from the same samples in the McArthur Basin.

Figure 7-13. Measured mean maximum reflectances for lamalginite and bitumen plotted against their calculated vitrinite reflectances from methylphenanthrene indices (MPI-1). Superimposed are the limits of measured reflectances for vitrinite and liptinite (after Murchison et al., 1985) and trend lines for telalginite and lamalginite (A.C. Cook, unpublished data), from the Phanerozoic.

Figure 7-14. Hydrocarbon yield plotted against Tmax values where $S_2 \geq 0.20$ kg/tonne.

Figure 7-15. Hydrocarbon yield to 250 mg/g TOC plotted against Tmax values where $S_2 \geq 0.20$ kg/tonne, in the range 400-500° C. The line encloses the oil window.

Figure 7-16. Hydrocarbon yield plotted against Tmax values where $S_2 \geq 0.20$ kg/tonne, for the various organic matter types within the Tmax range 400-500° C and yield range 0-250 mg/g TOC. The line encloses the oil window.

are from the zone where free oil was found by Jackson et al. (1986) and clearly contain migrated hydrocarbons.

The oil-window (Figure 7-15) appears to lie between Tmax values of 425 and about 470° C and the zone of maximum oil-generation is at about 440° C. Maximum yields of about 200 mg/g for McArthur Basin organic matter are shown in Figure 7-

15 whereas maximum yields of 150 mg/g are reported from Phanerozoic sediments containing Type I kerogen (Tissot and Welte, 1984) suggesting that some migrated hydrocarbons may have contributed to these yields. Lower maximum yields are reported from sediments containing Type II (100 mg/g TOC) and Type III kerogens (70 mg/g TOC) (Tissot and Welte, 1984).

Fluorescent lamalginite is the main organic matter type for Tmax values below 440°C whereas nonfluorescent lamalginite and bitumen dominate in samples having Tmax's greater than 440°C (Figure 7-16). The loss of fluorescence in lamalginite therefore appears to occur near the middle of the oil-window and is clearly associated with hydrocarbon generation.

7.6 Reflectances versus extractable hydrocarbon yields.

The beginning of the oil window appears to start abruptly at a mean maximum reflectance of about 0.15% (fluorescent lamalginite) and finishes at about 1.4% (nonfluorescent lamalginite and/or bitumen) (Figure 7-17).

7.7 Calculated vitrinite reflectances derived from MPI-1 indices versus extractable hydrocarbon yield.

The calculated vitrinite reflectance value for the onset of hydrocarbon generation is about 0.6%. The end of the oil-window is not clear from the data but is somewhere between 1.30 to 1.60% (Figure 7-18).

Figure 7-17. Yield of extractable hydrocarbons versus mean maximum reflectances (mean maxRo%) in the range 0-2%. The line encloses the oil-window.

Figure 7-18. Calculated vitrinite reflectances from MPI-1 indices (Rc%) plotted against hydrocarbon yields.

CHAPTER 8

LEVELS OF MATURATION WITHIN THE McARTHUR BASIN

8.1 Introduction

In the previous chapter the range of values for some maturation indices with respect to hydrocarbon generation was established. Maturation levels for organic matter in the McArthur Basin vary considerably and range from being at least marginally mature to overmature for hydrocarbon generation (Figure 8-1, Table 8-1). In this chapter, the youngest of the groups in the McArthur Basin, the Roper Group, is examined first as interpretation of maturation levels within this group is less complex and the results assist in the interpretation of maturation levels in the older groups.

8.2 Maturation levels in the Roper Group

Dolerite sills are common within the Roper Group and contact metamorphism related to these sills has produced localised and probably elongate zones of overmature organic matter. Reflectances of nonfluorescent lamalginite and/or bitumen near a dolerite sill, 174 m thick, within the Corcoran Formation in the Broadmere 1 well, have clearly been affected by contact metamorphism (Figure 8-2). No reliable Tmax values are available for comparison from near this dolerite sill. Reflectances of nonfluorescent lamalginite near a dolerite sill, 73 m thick, in DDH Urapunga 5 have also been similarly affected.

Figure 8-1. Maturation levels for organic matter in core from DDH's examined within the McArthur Basin. (U1-6 = DDH's Urapunga 1-6; MNT3 = DDH MANT79-3).

Group/Formation	Tmax range (C°)	mean maxRo% range	Rc% range
Roper Group			
McMinn Fm.	430 - 488	0.16 (fl) - 3.49 (nf)	n.d.
Velkerri Fm.	437 - 459	0.23 (fl) - 3.42 (nf)	0.68 - 2.48
Cobanbarini Fm.			
"Cat Creek Member"	n.r.d.	0.39 (fl)	n.d.
"Lansen Creek Shale Mbr."	436 - 468	0.27 (fl) - 1.74 (nf+bit)	0.86
Bessie Creek Sst.	n.r.d.	1.46 (nf+bit)	n.d.
Corcoran Fm.	n.r.d.	1.35 (nf+bit) - 5.24 (nf+bit)	n.d.
Abner Sst.	n.r.d.	2.39 (nf+bit) - 5.34 (vb)	n.d.
Crawford Fm.	n.r.d.	1.80 (nf)	n.d.
Mainoru Fm.	n.r.d.	1.48 (nf) - 3.86 (nf+bit)	n.d.
"Mantungula Fm."	n.r.d.	2.78 (nf)	n.d.
Nathan Group			
Balbarini Dolomite	437	0.79 (vb), 4.19 (vb+pdb)	0.40
McArthur Group			
Stretton Sst.	n.r.d.	n.d.	n.d.
Yalco Fm.	426 - 458	0.14 (fl) - 0.789(nf)	0.68 - 0.91
Lynott Fm.	440 - 551	1.34 (nf+bit) - 2.76 (pdb)	0.77
Reward Dolomite	441 - 475	1.12 (vb) - 2.60 (vb)	n.d.
Barney Creek Fm.			
Glyde River Subbasin	429 - 466	0.05 (fl) - 1.05 (nf+bit)	0.58 - 0.86
Central and northern			
Batten Trough	437 - 551	1.24 (pdb) - 5.39 (db)	0.65 - 2.48
Teena Dolomite	454	1.83 (vb) - 2.81 (vb+db)	n.d.
Emmerugga Dolomite	n.d.	2.43 (vb), 3.05 (vb)	n.d.

Table 8-1. Ranges of Tmax, reflectances and calculated vitrinite reflectances derived from the MPI-1 indices (Rc%) for each formation examined in the McArthur Basin. The abbreviations enclosed in brackets after the reflectance values represent the type of organic matter measured to obtain the individual reflectance values where "fl" = fluorescent lamalginite, "nf" = nonfluorescent lamalginite, "bit" = bitumen, "pdb" = patchy dispersed bitumen, "db" = disseminated bitumen, and "vb" = vein bitumen. The Tmax values given are those where S2 ≥ 0.2 mg/g and where there is no suppression of the Tmax value due to migrated oil. ("n.r.d." = no reliable data, and "n.d." = no data).

Figure 8-2. Reflectances (Ro%) of nonfluorescent lamalginite and/or bitumen, and Tmax, versus depth for the wild-cat oil well, Broadmere 1, Roper Group. The range of reflectances is represented by the horizontal line, the mean by the vertical line and the 95% confidence limits of the mean by the boxes. Tmax values are those where S2 $\geq$ 0.20 and there is no suppression of values due to migrated oil.

Maturation levels of organic matter in the top sections of DDH's Urapunga 4 and 82/3, and in the lower sections of DDH's Urapunga 3 and B8 (Figure 8-3) have probably also been affected by contact metamorphism. Outcrop of a dolerite sill occurs close to, and stratigraphically above, DDH Urapunga 4 (J. Jackson, pers. comm.) and dolerite sills occur just below the bases of DDH's Urapunga 3 and B8, and stratigraphically above DDH 82/3, based on interpretation of geological maps of the region.

Organic matter in the McMinn, Velkerri and Cobanbarini Formations is marginally mature to mature where it has not been affected by contact metamorphism. Organic matter in the

Bessie Creek Sandstone and older formations is at least marginally overmature (Table 8-1).

Maturation levels as defined by reflectance values, generally increase with the age of the formations in the Roper Group (excluding the organic matter affected by contact metamorphism) (Figure 8-4). Tmax values for the McMinn Formation are mostly less than Tmax values for the older Velkerri or Cobanbarini Formations unless affected by contact metamorphism (Figure 8-5). Tmax values are unreliable in

Fig

Figure 8-3. Mean maximum reflectances (mean maxRo%) of nonfluorescent lamalginite and/or bitumen except where indicated, and Tmax, versus depth for DDH's B8, Urapunga 3 and 4, and 82/3, Roper Group. Tmax values are those where S2 ≥ 0.20 and there is no suppression of values due to migrated oil.

- McMinn Fm., fluorescent lamalginite
- McMinn Fm., nonfluorescent lamalginite or oncalginite and bitumen
- ◇ Velkerri Fm., fluorescent lamalginite
- ◆ Velkerri Fm., nonfluorescent lamalginite and/or bitumen
- ▷ Cobanbarini Fm., fluorescent lamalginite
- Cobanbarini Fm., nonfluorescent lamalginite or nonfluorescent lamalginite and bitumen
- ▣ Bessie Creek Sst., nonfluorescent lamalginite and/or bitumen
- ▤ Corcoran Fm., nonfluorescent lamalginite and/or bitumen
- + Abner Sst., nonfluorescent lamalginite and/or bitumen
- × Crawford Fm., nonfluorescent lamalginite
- × Mainoru Fm., nonfluorescent lamalginite and/or bitumen
- "Mantungula Fm.", nonfluorescent lamalginite

Figure 8-4. Mean maximum reflectances for fluorescent lamalginite or nonfluorescent lamalginite and/or bitumen (mean maxRo%) plotted against depth, for formations in the Roper Group. The outlined reflectance values have been affected by contact metamorphism.

Figure 8-5. Tmax values plotted against depth for formations of the Roper Group. Tmax values are those where S2 is greater than 0.2 mg/g, and the values show no suppression due to migrated oil. The outlined Tmax values have been affected by contact metamorphism.

formations older than the Cobanbarini or Velkerri Formations as the older formations are organically lean and overmature.

The levels of maturation are fairly similar for the same formations over a wide areal extent. Such a pattern of coalification is consistent with the concept that the Roper Group formed during the sag phase of the basin's development and that the sedimentary rocks in the group have subsequently had a relatively uniform geological history. The main stage of

coalification must have been associated with a phase or phases of relatively uniform subsidence. The localized zones of contact metamorphism were probably superimposed upon the regional pattern but it is possible that at least in part, the contact alteration predates much of the regional rank change, the evidence being, however, equivocal.

8.3 Maturation levels in the McArthur and Nathan Groups

Maturation levels in these groups range from being at least marginally immature to overmature. Maturation of organic matter in these groups has probably not been affected by contact metamorphism due, as in the case of the Roper Group, to the intrusion of dolerite sills. No igneous intrusions of any kind have been observed in this group (Jackson et al, 1987a). Anomalously high maturation indices do occur, however, in the McArthur Group in the Batten Trough.

Organic matter in core from two drill holes (M17/08, N27/63) in the Barney Creek Formation which passed through base metal mineralisation in the H.Y.C. deposit, have anomalously high reflectance and Tmax values at depths between about 250 to 350 m (Figures 8-6,7). This organic matter occurs within thin (<3mm thick), lutite beds within conformable, centimetre-thick, sulphide-rich bands containing pyrite, sphalerite, galena and chalcopyrite (in descending order of abundance). It consists mainly of disseminated, or in places, patches, of irregularly shaped bitumen pieces generally less

Figure 8-6 Measured reflectances (horizontal line = range, vertical line = mean, and rectangular boxes = 95% confidence limits of the mean), calculated reflectances from MPI-1 indices using equation 1 (x) or equation 2 (open diamond shape), and Tmax values versus depth for DDH M17/08, H.Y.C. lead-zinc deposit, Barney Creek Formation. The Tmax values given are those where $S_2 \geq 0.2$ mg/g and where there is no suppression of the Tmax value due to migrated oil. The abbreviations "nf. lam." = nonfluorescent lamalginite, "v.b." = vein bitumen, "m.b." = matrix bitumen, "p.d.b." = patchy dispersed bitumen, and "d.b." = disseminated bitumen.

than 10 microns in size. In one sample (DDH N27/63, 313.0 m), the organic matter appears as discrete, elongate bodies of nonfluorescent lamalginite, up to 30 microns long by generally less than 5 microns wide.

The H.Y.C. deposit occurs in the central region of the Batten trough (Figure 8-1) and is by far the largest of a number of base-metal deposits in the McArthur Group (Lambert and Scott, 1973). It contains an estimated 227 million tonnes of ore with an average grade of 9.2% Zn, 4.1% Pb, and 41 g/t Ag

Figure 8-7 Measured reflectances (horizontal line = range, vertical line = mean, and rectangular boxes = 95% confidence limits of the mean), calculated reflectances from MPI-1 indices using equation 1 (x) or equation 2 (open diamond shape), and Tmax values versus depth for DDH N27/63, H.Y.C. lead-zinc deposit, Barney Creek Formation. The Tmax values given are those where $S_2 \geq 0.2$ mg/g and where there is no suppression of the Tmax value due to migrated oil. The abbreviations "nf. lam." = nonfluorescent lamalginite, "v.b." = vein bitumen, "p.d.b." = patchy dispersed bitumen, and "d.b." = disseminated bitumen.

(Buchanan, 1984). It extends over an area of approximately 1.5 km² and consists of thin, closely-spaced, conformable sulphide bands in shales having a total thickness of generally about 55 m but reaching up to 130 m (Lambert and Scott, 1973). It probably formed from either syngenetic (Smith and Croxford, 1973, Lambert and Scott, 1973; Murray, 1975; Lambert, 1976) or epigenetic (Williams, 1978b) hydrothermal metalliferous solutions. The evidence as to whether the deposit formed syngenetically or epigenetically is equivocal (Williams, 1978b).

The mineralising solutions had a temperature ranging from about 100° to 260°C based on the sulphur isotope fractionations between galena and sphalerite (Smith and Croxford, 1973; Williams and Rye, 1974).

Epigenetic, discordant, Pb-Zn-Cu mineralisation occurs at a number of deposits near the H.Y.C. and closer to the Emu Fault, in the Emmerugga Dolomite and Cooley Dolomite Member (Williams 1978a). Textural and mineralogic characteristics of the mineralisation indicate that early stage, low-temperature (<200°C), copper bearing solutions and later stage, Pb-Zn bearing solutions, were responsible for the mineralisation (Williams, 1978a). The contours of Cu/(Pb+Zn) ratios suggest that the mineralising fluids emanated from the Emu Fault and spread westwards towards the H.Y.C. (Williams, 1978a).

An increase in heat flow, emanating from relatively hot mineralising solutions as the H.Y.C. deposit formed, and the resulting higher temperatures in adjacent sediments, produced a more rapid maturation of the adjacent organic matter. The anomalously higher maturation indices in the zone of base-metal mineralisation in the H.Y.C. deposit therefore signal the effects of a form of contact metamorphism, in this case, produced by hot mineralised solutions.

Anomalously high maturation reflectances of patchy dispersed, disseminated or vein bitumen are evident elsewhere from the central region of the Batten Trough in the Barney Creek Formation, Reward and Emmerrugga Dolomites (DDHs BJ1, 30.6 m; Mant 79-3, 279.8 m; McA10, 139.3 m and 160.7 m).

Figure 8-8. Mean maximum reflectances (maxRo%) of fluorescent lamalginite, nonfluorescent lamalginite and/or bitumen, and Tmax versus depth for three drill holes (GR4, 10 and 11) in the Barney Creek Formation, Glyde River Subbasin.

Veins of sphalerite+pyrite and sphalerite+carbonate occur in DDH McA10 (139.3 m) clearly indicating that thermal activity from the passage of mineralised solutions may have produced the anomalously high reflectances in this sample. However, no base-metal mineralisation was observed in the other cases. Nevertheless, hydrothermal fluids need not necessarily contain metals in solution, and yet could produce localised zones of increased temperatures.

Tmax values from near the bottom of DDH GR10 in the Barney Creek Formation of the Glyde River Subbasin, some 50 km to the south of the H.Y.C. deposit, show a sharp increase with increasing depth (Figure 7-4). Bitumen vein reflectances from this zone are slightly anomalously higher but not the calculated vitrinite reflectance values (Figure 7-5). Bitumen reflectances and Tmax values for DDH GR4 show a relatively sharp increase with depth near the bottom of the drill hole (Figure 8-8). Tmax values near the base of DDH GR11 also appear to increase sharply (Figure 7-6) although bitumen and nonfluorescent lamalginite reflectances, and calculated vitrinite reflectances from MPI-1 indices, show no such sharp increases (Figure 7-7). It is possible in the cases of DDH's GR10 and 11, that the Tmax values near the base of these wells are portraying a rapid change in maturation levels that neither the measured reflectances nor the methylphenanthrene indices have recorded, although the reason for this is not clear and requires further work.

Organic matter in the Barney Creek Formation to the north of the Glyde River Subbasin in the central and northern regions of the Batten Trough, have mostly higher maturation indices than in the Glyde River Subbasin (Figure 8-9). Maturation indices for formations in the McArthur Group from the central and northern areas of the Batten Trough generally show a considerable overlap in values even when those values which are considered anomalous are taken into account (Figure

Figure 8-9. Mean maximum reflectances (mean maxRo%) for fluorescent lamalginite, nonfluorescent lamalginite and/or bitumen, and Tmax values versus depth for the Barney Creek Formation. The Tmax values given are those where where $S_2 \geq 0.2$ mg/g and where there is no suppression of the Tmax value due to migrated oil. The boxed points are anomalous values which may have been produced by hydrothermal activity.

Figure 8-10. Mean maximum reflectances (mean maxRo%) for fluorescent lamalginite, nonfluorescent lamalginite and/or bitumen, and Tmax values versus depth for formations in the McArthur Group and the Balbarini Dolomite in the Nathan Group in the central and northern areas of the Batten Trough. The Tmax values given are those where $S_2 \geq 0.2$ mg/g and where there is no suppression of the Tmax value due to migrated oil. The boxed points are anomalous values which may have been produced by hydrothermal activity.

8-10). They indicate a more complicated geological history for the McArthur Group than that of the Roper Group. Hydrothermal activity probably played a considerable role in the maturation process but it is unlikely that it affected all the organic matter in this region. The Batten Trough, up until near the end of

deposition of the Balbarini Dolomite, was an active tectonic environment (Jackson et al, 1987a) in which there were differing rates of subsidence in various parts of the trough (Plumb et al., 1980). Deposition of the sediments took place in a series of northerly trending half-grabens with greatest subsidence occurring in the western areas of the half-grabens (Muir, 1983a). This activity was probably the final phase of extension prior to the sag phase during which sediments of the Roper Group were deposited. The thickness of the continental lithosphere over the hot asthenosphere in the Batten Trough may, therefore, have been variable and resulted in significant lateral variations in geothermal gradients throughout the trough. By the time the Roper Group was deposited, geothermal gradients throughout the region were relatively uniform and there is no evidence to suggest that there were significant variations in rates of subsidence or uplift within the Batten Trough after deposition of the Nathan Group. Lateral variations in subsidence rates and in geothermal gradients within the half-graben structures of the Batten Trough during deposition of the McArthur Group and the Balbarini Dolomite are the most likely causes for much of the overlap of maturation levels between individual formations of the McArthur Group observed here. Hydrothermal activity associated with active faults during this time also contributed significantly to the maturation process in places.

CHAPTER 9

GEOLOGICAL MODELLING AND TIMING OF OIL GENERATION

9.1 Introduction

An attempt can now be made to construct geological models for specific wells and regions to assess past basinal thicknesses and the timing of oil generation in the Barney Creek Formation (McArthur Group) and the Velkerri Formation (Roper Group). Both formations are clearly the most organic-rich in the McArthur Basin (Figs. 5-1,2). Vitrinite reflectances are determined from these models and are compared to measured reflectances recalculated to vitrinite reflectances and to calculated vitrinite reflectances derived from the methylphenanthrene indices.

The widespread use of vitrinite reflectance for modelling in Phanerozoic basins is due to its advantages over a number of other maturation indices such as clay mineralogy, zeolites, fluid inclusions, apatite and zircon fission track annealing and stable isotopes in that it covers a wide temperature range of about 25°C to at least 400°C and is not "metamorphic regressive" (Price and Barker, 1985). Data can be obtained for a wide range of samples and restrictions on sample type are less demanding than many other methods (Cook, 1988). It is assumed that reflectances measured from organic matter in the McArthur Basin are also not "metamorphic regressive".

The level of vitrinite reflectance is considered by many to be a function of time and temperature (e.g. Karwell, 1956; Lopatin, 1971; Hood and Castano, 1974, Connan, 1974; Buntebath, 1978) whereas Price (1983) considers that it is purely a function of the maximum temperature encountered by the organic matter and that

geological time plays no role. Price (1983) examined the literature supporting the contention that geological age is a factor in organic metamorphism and concluded that in those studies where "hard scientific documentation" was available (Karweil, 1956; Lopatin, 1971; and Connan, 1974) the levels of organic metamorphism are better explained by high palaeogeothermal gradients resulting from major geological activity rather than by invoking geological time as a factor. He plotted vitrinite reflectance data from a number of basins ranging from 2 to 240 m.y. old which he considered are currently at or near maximum geothermal gradients and showed that the Ro data show a strong correlation with temperature but not with time.

Lopatin (1971) developed a "time-temperature index" (TTI) to quantify the effects of both time and temperature on the maturation of organic matter in sediments based on data from Huck and Karweil (1955). Lopatin proposed that definite TTI values correspond to the different stages of oil generation, however Waples (1980) considered they were incorrect because of errors in his original geological reconstruction. Waples (1980) developed a new scale of TTI versus vitrinite reflectance based on unpublished Chevron data. It was assumed by Lopatin (1971) and others before and after him (e.g. Karweil, 1956; Hood and Castano, 1974; Hood et al. 1975) that the overall complex processes in oil generation and coalification can be generalised as a simple, first-order chemical reaction where the reaction rate (k) is a function of absolute temperature (T) and activation energy (E) as expressed by the Arrhenius equation, $k = Ae^{-E/RT}$. Tissot et al. (1987) comment that the values of maturation indices such as vitrinite

reflectances, result from complex, poorly known, kinetics and that the TTI index does not take into account the differing rates of reactions of different organic matter types, but this argument is separate from that concerning the significance of time.

Given that the geological history of the McArthur Basin can only be very roughly reconstructed, use of simple "first-order" empirical methods is warranted rather than more sophisticated approaches. Two methods are used: (1) the Lopatin (1971) method as modified by Waples (1980), and (2) Price's (1983) method.

9.2 Thermal history of the McArthur Basin

Use of either Lopatin-Waples' or Price's methods requires, at the very least, a knowledge of the current geothermal gradients and preferably, knowledge of past geothermal gradients. Changes in heat flow in the McArthur Basin over its geological history must have occurred, particularly during the extensional tectonic phase of its development. By the time sediments of the Roper Group started to be deposited, during the sag phase, geothermal gradients had become relatively stable.

An inferred cooling history of Proterozoic rocks of the Pine Creek Geosyncline in the East Alligator River region, which had been overlain by sediments of the McArthur Basin, and which is adjacent to the present north-east margin of the McArthur Basin, has been derived from fission-track annealing temperatures of a number of minerals (Koul et al., 1988). Their results indicate that from 1428 Ma, at about the end of deposition of the Roper Group, to well into the Phanerozoic, a smooth cooling history resulted from declining radiogenic heat production and gradual stripping of the insulating sedimentary cover. Koul et al. (1988)

Figure 9-1. Temperature versus depth for DDH 82/5 showing all data (a) and data from about 150 m depth downwards (b) where temperatures are unaffected by near-surface perturbations.

Figure 9-2. Temperature versus depth for DDH 82/7 showing all data (a) and data from about 150 m depth downwards (b) where temperatures are unaffected by near-surface perturbations.

comment that the cooling curve may have been influenced by several relatively short-term low-magnitude events such as the intrusion of dolerite dykes but they consider it "intuitively unreasonable that such small additions of magma could raise the temperature of the host rocks anything but locally and for a relatively short time".

9.3 Present geothermal gradients

Temperatures of the two measured Amoco stratigraphic drill holes show a regular increase in temperatures with depth from about 150 meters (Figures 9-1,2). The geothermal gradient at DDH 82/5 is 33.1 C°/km (zero intercept of 28.8° C) and 28.7 C°/km at 82/7 (zero intercept of 30.5° C), which are both slightly above the average geothermal gradient in the upper crust of 25 C°/km (Melton and Giardini, 1984).

Temperature perturbations near the surface are probably due to ground-water movement and heating of the rock by insolation and were deleted when determining the geothermal gradients. The ambient air temperature at DDH 82/5 was 31.1° C and 32.2° C at DDH 82/7.

9.4 Geological models

9.4.1 *Glyde River Subbasin*

A number of geological models can be developed for the geological history of the Glyde River Subbasin. Information regarding possible thicknesses that may have developed over the Barney Creek Formation (Table 9-1) has been derived from regional studies of the southern McArthur Basin.

Maximum and minimum thicknesses for the McArthur and Nathan Groups in the southern McArthur Basin (Jackson et al., 1987a) were used together with an extrapolated thickness of the Roper Group over the Glyde River subbasin of 600 m (Jackson et al., 1987b). Maximum thicknesses of nearby Cambrian Georgina Basin sediments (Bukalara Sandstone and Top Springs Limestone) and Cretaceous sediments (Mullaman Beds) were obtained from Plumb and Rhodes (1964). Based on field evidence, the amount of erosion that occurred after deposition of the Nathan Group and prior to the deposition of the Roper Group in the southern McArthur Basin, varies between 240 and 1805 m (Jackson et al., 1987a). No information regarding the amount of erosion that occurred between the Umbalooga and Batten Subgroups and the McArthur and Nathan Groups is available. Rates of sedimentation and erosion can only be guessed at.

Given the paucity of data, only very generalised models are attempted. The first set of models (1a to 8a) is for the top of the Barney Creek Formation in the subbasin whereas the second set (1b to 8b) is for near the bottom of the formation in DDH GR7. The Barney Creek Formation attains a maximum thickness in the Glyde River Subbasin in this well and organic matter at that depth has not been affected by hydrothermal metamorphism. The range of lamalginite reflectances for drill core within the top 50 meters in the Glyde River Subbasin is 0.05 - 0.16% giving an equivalent vitrinite reflectance range of about 0.5 - 0.7%. Patchy dispersed bitumen reflectances for DDH GR7 at a depth of 854 m, near the base of the Barney Creek Formation (820 m below the Bukalara Sandstone unconformity), have a mean value of 1.0% and the same equivalent vitrinite reflectance.

The major variables in modelling the Glyde River Subbasin are the thickness of the McArthur and Nathan Groups that may have overlain the Barney Creek Formation, their depositional time (Table 9-2) and the amount eroded prior to deposition of the Roper Group.

age/unit	thicknesses (m)	radiometric age (Ma)
Cretaceous		
Mullaman Beds	100	
---- <i>regional unconformity</i> -----		
Late-Early to		
Early-Middle Cambrian		
Top Springs Limestone	100	
Early Cambrian		
*Bukalara Sandstone	300	
---- <i>regional unconformity</i> -----		
Middle Proterozoic		
ROPER GROUP	600	1429 ± 31 (McMinn Formation)
---- <i>regional unconformity</i> -----		
NATHAN GROUP		
Dungaminnie Formation	240+	
Balbarini Dolomite	1500	
Smythe Sandstone	0 -65	
---- <i>regional unconformity</i> -----		
McARTHUR GROUP		
Batten Subgroup		
Amos Formation	50 - 80	
Looking Glass Formation	65+	
Stretton Sandstone	30 - 270	
Yalco Formation	up to 250	
Lynott Formation	50 - 600	
---- <i>local unconformity</i> -----		
Umbalooga Subgroup		
*Reward Dolomite	10-350	
*Barney Creek Formation		1690 ± 27

Table 9-1. Thicknesses and ages of sedimentary units that probably overlaid the Barney Creek Formation in the Glyde River Subbasin. * = formations present in the subbasin.

Time-temperature indexes (TTI) were calculated arithmetically from these models and converted to equivalent vitrinite reflectances using Waples (1981) data, assuming that the present day geothermal gradient of about 30 C°/km. has

remained constant. A zero intercept of 20° C is also assumed, a figure lower than the present zero intercept of 30° C, but is probably a reasonable average figure given the wide range of climatic conditions experienced by the McArthur Basin during the Proterozoic, ranging from arctic to tropical (Idnurm and Giddings, 1988). A constant geothermal gradient of 30 C°/km with a zero intercept of 20° C was also used in calculating the maximum temperatures reached and converting them into vitrinite reflectances according to Price (1983). Reflectance values derived from both methods for all the models are shown in Tables 9-3 and 9-4 and the complete calculations are given in Appendix M.

Unit	thickness(es) (m)	Time interval (Ma.)
McArthur and Nathan Groups (above Barney Creek Fm.)	2,000 -3420	1690-1670 1690-1459
Roper Group	600	1449-1429
Bukalara Sst.	300	570-560
Top Springs Lst.	100	510-500
Mullaman Beds	200	100-90

Table 9-2. Thicknesses and depositional times used in models for the Glyde River subbasin.

The results of the Lopatin-Waples modelling show major differences associated with the varying assumptions. The results, using Price's method, have a small range showing that this method

Depositional-erosional models	method used		Observed equivalent Rv%
	Lopatin's, Rv%	Price's, Rv%	
1a. Maximum deposition of 3420 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1670 Ma followed by erosion of 1805 m to top of Amos Fm. from 1670 to 1449 Ma. Deposition of 600 m of Roper Group from 1449 to 1429 Ma followed by erosion to top of Barney Creek Fm from 1429 to 570 Ma. Deposition and erosion of Cambrian and Cretaceous units.	1.5	0.6	0.5 - 0.7
1b. As for above but including 820 m of Barney Creek Creek Fm. deposited from 1692 to 1690 Ma.	2.2	0.7	1.0
2a. Maximum deposition of 3420 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1670 Ma followed by erosion of 240 m to top of Balbarini Dol. from 1670 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	2.2	0.7	0.5 - 0.7
2b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	3.0	0.8	1.0
3a. Maximum deposition of 3420 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1459 Ma followed by erosion of 1805 m to top of Amos Fm. from 1459 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	1.4	0.6	0.5 - 0.7
3b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	2.0	0.7	1.0
4a. Maximum deposition of 3420 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1459 Ma followed by erosion of 240 m to top of Balbarini Dol. from 1459 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	2.0	0.7	0.5 - 0.7
4b. As for above but including 820 m of Barney Creek Fm.	2.6	0.8	1.0

Table 9-3. Depositional-erosional models for the Glyde River Subbasin, assuming maximum thicknesses of the McArthur and Nathan Groups above the Barney Creek Formation in the Glyde River subbasin, together with calculated vitrinite reflectance percentages (Rv%) derived from Lopatin-Waples' and Price's (1983) methods assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C; and the observed equivalent vitrinite reflectances. Tables showing complete calculations are given in Appendix M.

Depositional-erosional models	method used		Observed equivalent Rv%
	Lopatin's, Rv%	Price's, Rv%	
5a. Minimum deposition of 2000 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1670 Ma followed by erosion of 1805 m to top of Amos Fm. from 1670 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	0.7	0.4	0.5 - 0.7
5b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	1.2	0.5	1.0
6a. Minimum deposition of 2000 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1670 Ma followed by erosion of 240 m to top of Balbarini Dol. from 1670 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	1.1	0.5	0.5 - 0.7
6b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	1.8	0.6	1.0
7a. Minimum deposition of 2000 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1459 Ma followed by erosion of 1805 m to top of Amos Fm. from 1459 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	0.7	0.4	0.5 - 0.7
7b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	1.2	0.5	1.0
8a. Minimum deposition of 2000 m of McArthur and Nathan Groups above Barney Creek Fm. from 1690 to 1459 Ma followed by erosion of 240 m to top of Balbarini Dol. from 1459 to 1449 Ma. Deposition and erosion of Roper Group and Phanerozoic units as for model 1.	1.0	0.5	0.5 - 0.7
8 b. As for above but including 820 m of Barney Creek Fm. deposited from 1692 to 1690 Ma.	1.7	0.6	1.0

Table 9-4. Depositional-erosional models for the Glyde River Subbasin, assuming minimum thicknesses of the McArthur and Nathan Groups above the Barney Creek Formation in the Glyde River Subbasin, together with calculated vitrinite reflectance percentages (Rv%) derived from Lopatin-Waples' and Price's (1983) methods assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C; and the observed equivalent vitrinite reflectances. Tables showing complete calculations are given in Appendix M.

Figure 9-3. Burial history for the Barney Creek Formation, DDH GR7, Glyde River Subbasin, from the depositional-erosional model 5 (Table 9-4)

Figure 9-4. Burial history for the Barney Creek Formation, DDH GR7, Glyde River Subbasin, from the depositional-erosional model 7 (Table 9-4).

is insensitive to major changes of assumptions about stratigraphic thickness.

None of the models gives a perfect fit when vitrinite reflectances derived from using either the Lopatin-Waples or Prices methods are compared to the observed equivalent vitrinite reflectances. Models which best fit using the Lopatin-Waples method, are those which have a minimum thickness of 2000 m for the McArthur and Nathan Group sediments overlying the Barney Creek Formation combined with maximum erosion of 1805 m prior to deposition of the Roper Group (Table 9-4, models 5 and 7; Figures 9-3 and 9-4). A better fit could be achieved if it is assumed that the minimum thickness of the overlying McArthur and Nathan Group sediments was several hundred meters less than given and that most of it was eroded away prior to deposition of the Roper Group sediments.

Almost all vitrinite reflectances derived by using Price's method, with the exception of models 5 and 7, fit the observed values for the top of the Barney Creek Formation but are all lower than observed for the base of the formation.

9.4.2 Central and Northern Batten Trough

Maturation levels for the Barney Creek Formation are mostly higher than in the Glyde River Subbasin (Chapter 8). Hydrothermal metamorphism, higher geothermal gradients and greater depths of burial are the most probable causes.

9.4.3 Roper Group

For modelling the maturation levels of the Roper Group, Amoco's well, Broadmere 1, is used as it is the deepest well in the McArthur Basin, reaching a total depth of 2174 m (Figure 9-4). It

passes through most of the lower Roper Group and through 452 m of the Cobanbarini Formation at the base of the upper Roper Group, the Maiwok Subgroup. Unfortunately, the well-completion reports do not contain sufficient information in order to determine the geothermal gradient at Broadmere 1, so the average geothermal gradient of 30 C°/km with a zero intercept of 20° C is used in this modelling.

The Maiwok Subgroup reaches a maximum observed thickness of about 2000 m (Jackson et al., 1987b) and this figure is used together with the maximum observed thicknesses of Cambrian units (Bukalara Sandstone, 300 m; Top Springs Limestone, 100 m) and the Cretaceous Mullaman Beds (200 m) (Smith, 1964)

Figure 9-4. Depth versus reflectance (Ro%) for lamalginite and/or bitumen and stratigraphy of Broadmere 1. The trend line indicates the change in reflectances with depth assuming the absence of contact metamorphism from intrusion of a dolerite sill at about 1000 m.

for Broadmere 1. The top of Broadmere 1 is stratigraphically about 30 m below the nearest Cretaceous unconformity surface, 15 km to the south-east of the well. Dolerite sills were formed within the Roper Group at about 1280 Ma (McDougall et al., 1965) and have an aggregate thickness of about 300 m (Dunn, 1963). A dolerite sill, 174 m thick, occurs in Broadmere 1 within the lower Roper Group (Amoco Australia Petroleum Company, Well Completion Report, 1985).

As in the case of the Glyde River Subbasin, many variables are unknown. For example, total thicknesses of the sediments that overlie this well, rates of sedimentation and erosion, past geothermal gradients, and the age of start of deposition of the Roper Group are all poorly known. Cessation of deposition of the Roper Group occurred at 1429 ± 31 Ma (Kralik, 1982) although Page et al. (1984) regard this as a minimum age. For the purposes of this exercise the 1429 Ma age is used as the end of deposition of the Roper Group. Two times are used for the start of deposition at the base of Broadmere 1, one at 1529 Ma and the other at 1449 Ma, to gauge the affect depositional time has upon the Lopatin-Waples modelling. In the absence of any contrary data it is assumed, for the sake of simplicity, that rates of sedimentation and erosion are uniform.

The time taken for deposition of the Roper Group, be it 100 million years (Table 9-5, model 1) or 20 million years (Table 9-5, model 2) makes little difference to the overall result ($<0.1\%$) using the Lopatin-Waples approach. Both results ($R_v\% = 2.4$), however, are significantly lower than the observed reflectance of 3.5% (for nonfluorescent lamalginite and bitumen) for the base of

Depositional-erosional model	method used		Observed equivalent Rv%
	Lopatin Rv%	Price Rv%	
1. Deposition from 1529-1429 Ma of 2174m Roper Group at Broadmere 1 plus additional 1548m Maiwok Subgroup (total of 3722m); erosion of 500m Roper Group from 1429-1280 Ma, intrusion of 300m dolerite sills at at 1280 Ma; erosion of 1248m from 1280-570 Ma; deposition and erosion of Phanerozoic sediments.	2.4	0.6	3.5
2. Deposition from 1449-1429 Ma of 2174m Roper Group at Broadmere 1 plus additional 1548m Maiwok Subgroup (total of 3722m); erosion of 500m Roper Group from 1429-1280 Ma, intrusion of 300m dolerite sills at at 1280 Ma; erosion of 1248m from 1280-570 Ma; deposition and erosion of Phanerozoic sediments.	2.4	0.6	3.5
3. Deposition from 1439.74-1429 Ma of 452m Cobanbarini Fm. at Broadmere 1 plus additional 1548m Maiwok Subgroup (total of 2000m); erosion of 500m Roper Group from 1429-1280 Ma, intrusion of 126m dolerite sills at at 1280 Ma; erosion of 1248m from 1280-570 Ma; deposition and erosion of Phanerozoic sediments.	0.9	0.5	1.4
4. Deposition from 1439.74-1429 Ma of 452m Cobanbarini Fm. at Broadmere 1 plus additional 2548m Maiwok Subgroup (total of 3000m); erosion of 500m Roper Group from 1429-1280 Ma, intrusion of 126m dolerite sills at at 1280 Ma; erosion of 1248m from 1280-570 Ma; deposition and erosion of Phanerozoic sediments.	1.6	0.6	1.4

Table 9-5. Depositional-erosional models at Broadmere 1, Roper Group, together with calculated vitrinite reflectance percentages (Rv%) derived from Lopatin-Waples' and Price's (1983) methods assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C, and the observed equivalent vitrinite reflectances. Complete calculations are given in Appendix M.

the well. Varying the time of deposition of the Roper Group obviously makes no difference to reflectances using Price's method which are considerably lower than the observed reflectance. Reflectance values for the base of the Cobanbarini Formation at Broadmere 1 are also too low, regardless of method (Table 9-5, model 3).

A number of reasons can be given to explain the lower than observed reflectances including:

- 1) the sedimentary thickness of the Maiwok Subgroup of the Roper Group may have been considerably thicker than observed today and included sediments which have been totally eroded away;
- 2) the aggregate thickness of dolerite sills at Broadmere 1 may have been greater;
- 3) sedimentary thicknesses of the Phanerozoic units may have been considerably greater, or
- 4) geothermal gradients may have been higher than the present.

It would seem impossible to determine which of these factors or which combination of them is the most likely cause. However, the evidence of Koul et al. (1986) does suggest that past geothermal gradients were much the same as today. It is probable that sedimentary thicknesses of the Cambrian units never greatly exceeded those used in this model as it is likely that this region was a topographic high at the time of deposition of the Georgina Basin (Shergold and Druce, 1980) and remained so for all of the Phanerozoic. The major factors remaining, which could be reasonably varied, are the maximum thickness of the Maiwok Subgroup and the aggregate thickness of dolerite sills in the Maiwok Subgroup. The top of the Maiwok Subgroup is not preserved (Jackson et al, 1987b) and its original thickness could therefore

have been greater than 2000 m. It would seem unlikely that significantly thick dolerite sills intruded the sedimentary pile near the top of the Maiwok Subgroup; most were probably emplaced at lower levels. Increasing the thickness of the Maiwok Subgroup by 1000 m, assuming that the aggregate thickness of dolerite sills in the Subgroup remained at 300 m, would give greater agreement, using the Lopatin-Waples method (Table 9-5, model 4, Fig. 9-5). Using Price's method, however, the calculated value of 0.6% R_v versus an observed $R_o\%$ of 1.4 for the base of the Maiwok Subgroup, is clearly still too low.

Figure 9-5. Burial history for Broadmere 1 well, assuming that 3000 m of Maiwok Subgroup sediments were deposited (model 4, Table 9-5).

Unless geothermal gradients were higher than observed today, and there is some evidence to suggest they were not (Koul et al., 1986) then Price's method for calculating reflectances is invalid, and time has been an important element in the

maturation of organic matter in the Roper Group. It seems likely, given the results of this modelling using the Lopatin-Waples method, that the Maiwok Subgroup was significantly thicker than observed today.

9.5 Timing of the generation of oil

Oil generation in Phanerozoic sediments commences, according to the Lopatin-Waples model (Waples, 1980), at a TTI of 15 ($R_v\% = 0.65$), reaches peak oil generation at a TTI of 75 ($R_v\% = 1.00$) and ceases at a TTI of 160 ($R_v\% = 1.30\%$). For the McArthur Basin, oil generation commences at about a reflectance of 0.15% for fluorescent lamalginite which is equivalent to a vitrinite reflectance of between 0.55 to 0.65% and ceases at about 1.4% (Chapter 7). Oil generation probably reaches a peak between about 0.3 to 0.4% reflectance for fluorescent lamalginite which is equivalent to a vitrinite reflectance of between 0.7 to 0.9%. In terms of TTI values, oil generation starts at between 8 and 15, reaches a peak between about 34 and 50 and ceases at a value of 217. These values are therefore used in calculating the timing of oil generation.

Oil generation characteristics will vary due to differences in the original organic matter composition within a formation or between formations but such variations are probably within the ranges of the above TTI values. In addition, the unavoidably imprecise geological models used here to determine the timing of oil generation in the McArthur Basin means that such variations are probably insignificant.

Oil generation near the base of the Barney Creek Formation in the Glyde River Subbasin, commenced and reached a peak prior to

deposition of the Roper Group according to the best-fit models (models 5 and 7, Table 9-4). As the calculated Rv% value is slightly higher than the observed value (1.2 versus 1.0) then peak oil-production may have occurred soon after deposition of the Roper Group. The onset and peak oil production for the base of the Maiwok Subgroup (base of the Velkerri Formation and its equivalent, the "Lansen Creek Shale") occurred within one hundred million years after deposition of the Roper Group for the model which assumes that the Maiwok Subgroup was 1000 m thicker than observed today (model 4, Table 9-5). Oil generation probably also occurred, in places, adjacent to dolerite sills during and, for a limited time, after their intrusion.

Tissot and Welte (1984) comment that at peak oil generation the reaction rates do not double every 10° C, as assumed by the Lopatin-Waples method, but are multiplied by about 5, whereas the activation energies required to break chemical bonds within the organic matter are relatively weak at the onset of oil and gas generation and at this stage the reaction rates double for every 10° C rise. Therefore peak oil generation probably commenced at an earlier time than that given using the Lopatin-Waples method.

Onset and peak oil generation for organic matter above the base of both formations obviously occurred at some later time than at their base. Organic matter in the uppermost part of the Barney Creek Formation in the Glyde River Subbasin has yet to reach the peak oil generation stage.

The Barney Creek Formation in the Glyde River Subbasin and the Velkerri Formation (except where affected by contact metamorphism) are still within the oil-window and are potentially capable of producing more oil given the right

geological conditions. At some stage in the past, oil generation ceased in these formations as temperatures fell below a certain level. This level cannot be calculated from activation energies derived from high-temperature pyrolysis experiments and extrapolated to low-temperature geological systems via the Arrhenius equation as such calculations will result in a too high a temperature (Snowdon, 1979). Quantum mechanical tunnelling may be a significant factor at low-temperatures and the probability of tunnelling increases with a decrease in temperature and will result in the production of hydrocarbons at temperatures lower than those calculated from pyrolysis experiments (Snowdon, 1979). Gretener and Curtis (1982), using a modified Lopatin approach, consider that hydrocarbon generation in Phanerozoic sediments is almost at a standstill at temperatures below 50 to 70°C. The Barney Creek and Velkerri Formations are considerably older than Phanerozoic source rocks and hydrocarbons may have been generated, albeit at very slow rates, at low temperatures over a considerable period of time (Figure 9-6). However, preliminary data from fission track analyses of apatite suggest that the Roper Group sediments emerged from the oil window during the middle Palaeozoic (A. Gleadow, personal communication). There is a possibility, though, that bush fires have affected the results as the samples came from outcrop. Additional samples from drill core are currently being analysed.

Figure 9-6. Diagram showing main oil generation periods (solid line) and possible low-temperature (less than 70° C) oil generation periods (dashed line) for the base of the Velkerri Formation, and the base of the Barney Creek Formation at DDH GR7 in the Glyde River Subbasin.

CHAPTER 10

ORIGIN OF THE ORGANIC MATTER

10.1 Introduction

There is now well-documented evidence of organisms having existed on Earth since the Archaean which through most of the Proterozoic, were microscopic unicellular, colonial, or filamentous species existing as pelagic or benthic forms in the hydrosphere (Schopf, 1983). It was not until very late in the Precambrian that there is clear evidence for the existence of multicellular organisms (Glaessner and Wade, 1966). Palaeontological studies on the McArthur Basin have greatly contributed to this body of knowledge.

Since the first unpublished report of microfossils in the McArthur Basin in the McMinn Formation of the Roper Group by Norvick (1970), subsequent micropalaeontological studies have revealed an extensive microbiota preserved in a number of lithologies and formations (Croxford et al., 1973; Muir, 1974, 1976, 1982, 1983b; Hamilton and Muir, 1974; J. H. Oehler et al., 1976; J. H. Oehler, 1977; J. H. Oehler and Logan, 1977; D. Z. Oehler, 1978; Peat et al., 1978; Peat, 1979). A variety of single-cell, colonial, multicellular and filamentous micro-organisms have been described from all stratigraphic groups in the McArthur Basin. Stromatolites are present in the Tawallah and Nathan Groups and especially in the McArthur Group (Walter, 1972; Walter et al., 1988) but not in the Roper Group (Jackson et al., 1987a,b).

A varied microfossil assemblage occurs in the Wollogorang Formation, Tawallah Group, but none appears to be unique to this formation, as they also occur within the younger McArthur Group (Muir 1982).

Croxford et al. (1973), Muir (1974, 1976) and Oehler et al., (1976) have all reported the presence of microfossils in the Amelia Dolomite, McArthur Group, which are interpreted by Hofmann and Schopf (1983) as being colonial and unicellular spheroidal bacteria and/or cyanobacteria or cellular, filamentous bacteria and/or cyanobacteria. Hofman and Schopf (1983) describe additional microfossil taxa which include the genus *Tetraphycus* originally erected for tetrad clusters in the Balbarini Dolomite, Nathan Group, by Oehler (1978). *Eoentophysalis belcherensis* is also present in the Amelia Dolomite and as a taxon includes palmelloid and globular colonies of coccoids 2.5 - 9 micron across, with individual and common envelopes.

Hamilton and Muir (1974) examined kerogen extracted from shale associated with the H.Y.C. deposit in the Barney Creek Formation by acid digestion, and observed it commonly contained small cell outlines, averaging 2.6 microns long, some of which having been deformed by subsequent crystallisation of sulphides. J. H. Oehler (1977) examined numerous petrographic thin sections from chert blebs and layers within this shale and described a diverse assemblage of microfossils. Filamentous microfossils less than 1.5 microns thick and up to and exceeding 150 microns long, and encrusted with very fine-grained pyrite are commonly preserved as isolated structures whereas unicellular algal fossils which have cell diameters ranging from

0.7 to 21.7 microns, are preserved within clumps of amorphous organic matter up to several hundred microns in size. Oehler (1977) considers that the unicellular forms probably represent a 'planktonic rain' while the filamentous forms were probably washed into deeper environments from near-shore environments. Muir (1983b) suggests that the abundant small cells described by Hamilton and Muir (1974) were probably the result of algal blooms occurring in small shallow lakes and that the other micro-organisms had perhaps washed in from supralittoral and littoral flats during periods of flooding.

Micro-organisms from the Balbarini Dolomite, Nathan Group, contain a diverse assemblage of organic microfossils in stromatolitic cherts dominated by coccoid forms which have cell diameters ranging from 0.8 to 20.7 microns (D. Z. Oehler, 1978). One of the most abundant organisms in the assemblage is *Eoentophysalis belcherensis* Hofmann which have cell diameters ranging from 3.0 to 9.7 microns, averaging 4.1 microns. They occur almost exclusively in chert and in cherty patches within dolomite and appear to have formed the basically flat laminae of stromatolites which grew in an arid, intertidal to supratidal environment (D. Z. Oehler, 1978). Preservation of these microfossils within the laminae varies from being well-preserved to totally degraded with the laminae devoid of internal structure but still retaining the shape of the upper periphery of the *Eoentophysalis belcherensis* colonies.

The McMinn Formation of the Roper Group, besides containing a similar assemblage of micro-organisms to the older Groups, also contains large acritarchs up to 600 microns in diameter and short fragments of giant filaments up to 120

microns wide (Peat et al., 1978; Peat, 1979). Comparable fossils are known to occur throughout the whole of the Roper Group (Knoll, Walter and Summons, unpubl. in Summons et al., 1988).

Peat et al. (1978) considered that some of the larger acritarchs in the Roper Group were probably eucaryotes. Eucaryotes also contributed to organic matter in sediments as old as the Barney Creek (1690 Ma) although most of the McArthur Basin organic matter was probably derived from prokaryotes (Summons et al., 1988). The presence of steranes at all stratigraphic levels in extractable hydrocarbons, derived from the same sample set used in this study, is strong evidence for the existence of eukaryotic organisms whereas the high abundances of branched alkanes indicates that most of the organic matter was probably derived from prokaryotes (Summons et al., 1988).

Most of the microfossils described from the Tawallah and McArthur Groups occurred mainly in cherts, and to a lesser extent in stromatolitic carbonates and rarely from carbonaceous clastic sediments. However, in the Roper Group, the microfossil assemblages were found in fine-grained clastic sediments of the McMinn Formation (Peat, 1979).

The Wollogorang Formation in the Tawallah Group shows evidence of both hydrothermal and bacterial sulphate reduction (Donnelly and Jackson, 1988) as does pyrite sulphur associated with mineralisation in the McArthur Group (Smith and Croxford, 1973; Croxford et al., 1978; Williams, 1978a,b; Walker et al., 1983; Muir et al., 1985). Disseminated pyrite sulphur in the Barney Creek Formation from DDH GR10 at 137.3m from the Glyde River Subbasin has a $\delta^{34}\text{S}$ value of +22.9‰ indicating

that it formed by the action of sulphate-reducers in a restricted sulphate environment (Dr. I. B. Lambert, pers. comm.). Bacterial sulphate reduction also occurred in the Velkerri Formation of the Roper Group (Donnelly and Crick, 1988). Sulphate reducing bacteria therefore played a role in the degradation of the McArthur Basin's organic matter and no doubt form part of the source microbiota.

In Phanerozoic sediments, small, unicellular or thin-walled colonial planktonic or benthonic algae are the source microbiota for lamalginite (Hutton, 1987). Lamalginite in the Eocene oil-shale deposits of Queensland contain, in some cases, identifiable (to the genus level) stellate lacustrine colonial algae, *Pediastrum*; freshwater dinoflagellates, *Septodinium*; and freshwater acritarchs, *Cleistosphaeridium* (Hutton, 1982, 1986, 1987). The presence of these freshwater planktonic algae confirms what has previously been inferred from sedimentological studies that the lamalginites were deposited in a lacustrine environment (Hutton, 1986). The Eocene Green River Formation oil shale in the United States of America, also formed in a lacustrine environment and contains lamalginite (Ingram et al., 1983, Sherwood and Cook, 1984). Bradley (1964) identified *Pediastrum* in some samples of the Green River Formation oil shale and dinoflagellates (Hutton, 1982) or cyanobacteria (Hutton, 1986) have been suggested as possibly contributing to its original biomass. The retort oils from the Mahogany Zone, Green River Formation (Piceance Creek Basin) and the Kerosene Creek seam, Rundle Formation in Queensland, were both highly aliphatic ($H/C = 1.7$) suggesting a predominantly algal origin (Ingram et al., 1983). Chain length

distributions of the n-alkanes, 1-alkenes and nitriles indicate that algae were a major contributor but higher plants also contributed in a minor way to the shale-oil kerogens (Ingram et al., 1983).

Lamalginites in Cenozoic oil shales of Thailand originate from planktonic (e.g. *Pediastrum*) and possibly benthonic algal precursors within lakes having poor circulation and variable water levels so that transitions between swamps and lakes occur through time (Sherwood and Cook, 1984).

Lamalginites in the Cretaceous oil shales of the Toolebuc Formation in Australia is mostly derived from cysts of dinoflagellates and acritarchs with small contributions from indeterminate algal forms deposited under low energy, distal, offshore, marine conditions in an anaerobic environment (Sherwood and Cook, 1984).

10.2 Microfossils observed in this study

Only one probable microfossil, a tetrad of cells with a total diameter of 5 microns, was observed in ultra-violet light mode within fluorescing lamalginites of the Barney Creek Formation from the Glyde River Subbasin (Plate 2d). Given the simple structure of the tetrad it is not possible to positively identify it other than to suggest it was probably a small colonial micro-organism. Similarly sized cells, commonly forming tetrads, and composed of calcium phosphate, occur within a small nodule (1 mm in diameter) in another specimen from the Barney Creek Formation in the Glyde River Subbasin (Plate 18a-e). The nodule is one of a number of phosphate bodies which together with abundant lamalginites form a 2 mm thick

bed that has been scoured in one place prior to deposition of the overlying sediments (Plate 17). The other phosphatic bodies are thin (less than 0.5 mm) elongate forms up to several millimetres long that are made up of hexagonal crystals of phosphate (Plate 18d). It is not certain that the cellular-looking phosphate grains are fossil micro-organisms as this phosphate is made up of radiating crystals emanating from almost a point source (Plate 18e). The phosphate may have developed around tiny nucleii and the shapes it produced are a preferential form of inorganic growth.

Macerates of fluorescent lamalginite of the Barney Creek Formation from the Glyde River Subbasin are made up of irregularly shaped bodies up to several millimetres in diameter. The macerates commonly display an irregular cellular structure ranging from several to over 20 microns in diameter (Plate 10a-d). Many of the "cells" display straight-edges, commonly hexagonal or rhombic, indicating the former presence of mineral crystals such as carbonates, or have irregular boundaries. The variety of shapes and sizes of these "cells" suggests that they are probably inorganic in their origin having formed during diagenesis by the growth of minerals within the organic matter or by the organic matter being moulded around mineral grains during compaction.

The Barney Creek Formation also contains rare spherical structures lined with pyrite which may be single-cell microfossils (Plate 2b) or could equally be pyritic-rimmed organic matter of indeterminate origin. In one specimen, pyrite appears to rim fragments of clumps of cells (Plate 2c) but again this interpretation is speculative. Roughly rectangularly shaped

pyrite grains, several microns long by about one micron wide, form two chains up to about 30 microns long, one of which has a small side branch, within a titaniferous bitumen nodule in the Barney Creek Formation (Plate 11a). The size and appearance of them suggests that they could be fossil filamentous bacteria.

Some isolated pieces of nonfluorescent lamalginite in the Roper Group, up to several hundreds of microns long by a few microns thick, are made up of two, commonly parallel, strands of organic matter (Plate 2a) suggesting that they are probably compressed large single cells or acritarchs as described by Peat et al. (1978) and Peat (1979).

Microspheres of calcium phosphate, commonly exhibiting fluorescent rims, occur in some specimens from the Velkerri Formation and the "Lansen Creek Shale" (Plates 26e,f; 34G,H and 42). The microspheres range in size from about 2 to 7 microns in diameter but are generally less than 5 microns in diameter. They are commonly closely associated with, or imbedded in, lamalginite or bitumen. SEM images of the microspheres commonly show a bright rim of phosphate around a darker nucleus (Plate 42D,G) with the phosphate forming radially around the nucleus (Plate 42A). SEM X-ray probing of the nuclei of several microspheres found no evidence of mineral matter apart from calcium phosphate.

Hollow phosphate microspheres 10 to 25 microns in diameter have been observed by Soudry and Southgate (1989) in mudstone phosphorites from the Cambrian Duchess phosphate deposit in the Georgina Basin. They interpret these microspheres as the phosphatized remnants of solitary and colonial unicells because some of them contained two concentric encapsulated

envelopes, or cell-like units of 5 microns in diameter separated by rims of phosphate much thinner than the outer envelope of the sphere. No similar internal structures are present in the microspheres from the Roper Group but it is possible that they represent the fossilized remains of small unicells similar to those observed by Peat et al. (1978) from the McMinn Formation.

10.3 Origin of the Organic Matter Types in the McArthur Basin

10.3.1 *Lamalginite*

Palaeontological studies, outlined in the Introduction, show that a variety of micro-organisms inhabited the McArthur Basin. The contribution these micro-organisms made to the formation of lamalginite was no doubt significant and probably included small colonial forms in the case of lamalginite in the Barney Creek Formation, and small to large unicell forms in lamalginite from the Roper Group. However the absence of obvious microfossils within most of the lamalginite makes it difficult to assess the contribution made by the various micro-organisms. The remains of most micro-organisms have been rendered unrecognisable by the effects of bacterial degradation (particularly by sulphate reducers), compaction and diagenesis.

Compaction of the lamalginite may have been substantial. Oil shales of the Posidonia Shale in Germany are one fortieth of their original vertical dimension compared to a compaction of one quarter of interbedded limestones (Bandel and Knitter,

Figure 10-1. Outline drawings, perpendicular to bedding, of a large body of lamalginite from GR10, 37.4 m, (Plate 4b) showing normal dimensions (A) and decompacted shape given a 4 times decompaction (B).

1986). A visual representation of the shape of a decompacted body of organic matter can be made by tracing its outline from a photomicrograph and stretching it vertically by using a computer graphics program, (Mac SuperPaint). Decompacting a large lenticular piece of lamalginite from the Barney Creek Formation (Plate 4b), assuming that the lateral dimensions remained much the same during decompaction, by a factor of 4 produces a more lenticular shape (Figure 10-1) whereas decompaction by a factor of about 15 or more produces a body whose height is greater than its width (Figure 10-2). Any detrital or pelagic organic matter would normally settle on the bottom with its maximum dimension orientated horizontally.

Figure 10-2. Outline drawings, perpendicular to bedding, of a large body of lamalginite from GR10, 37.4 m, (Plate 4b) showing normal dimensions (A) and decompacted shape given a 15 times decompaction (B).

Organic matter which has its maximum dimensions orientated vertically are likely to have formed *in situ*. The degree of compaction in these sediments is not known and so it is not possible to clearly indicate the original form, prior to compaction, of the lamalginite. However, while some of the isolated lamalginite bodies in the Roper Group have formed from large, probably pelagic, acritarchs, the possibility clearly exists that at least some of the lamalginite formed as benthic microbial mats. It is possible also that some of the lamalginite formed from ripped up and redeposited microbial mats which originally grew in shallower parts of the basin. Microbial mats growing in the intertidal zone in parts of Shark Bay in Western Australia can be ripped up by wave action and form strand line deposits of irregularly shaped pieces (J. Bauld, pers. comm.).

10.3.2 *Oncalginite*

No microfossils were observed in, or associated with, oncalginite in oncolites from the one specimen examined from the McMinn Formation in the Roper Group. Early Proterozoic oncolites from the Nabberu Basin in Western Australia contain abundant filamentous cyanobacteria up to hundreds of microns long by 1 to 2 microns wide identified as *Gunflintia minuta* Barghoorn (Walter et al, 1976). Awramik (1984) considers that all oncolites were probably built by cyanobacteria which coated fragments that served as nucleii. Cyanobacteria therefore probably formed the oncalginite observed here.

10.3.3 Nonfluorescent Lamalginite and Bitumen

The diminution of fluorescence intensity in lamalginite with increasing depth is due to hydrocarbon generation and expulsion of hydrocarbons and gradual carbonisation or coalification of the remaining material. Lamalginite exhibiting low levels of fluorescence or no fluorescence at all commonly appears more deformed and disrupted than lamalginite exhibiting strong fluorescence (e.g. Plate 9a-e). This is particularly apparent in lamalginite from the Barney Creek Formation in the Glyde River Subbasin where it is possible to observe, in core from one drill hole, brightly fluorescent lamalginite from near the surface to nonfluorescent lamalginite near the bottom and a gradation in between. Disruption of lamalginite may become so great that its original morphology is destroyed and all that remains are a collection of small pieces which would appear as patchy dispersed bitumen, disseminated bitumen or matrix bitumen under the microscope (e.g. Plates 6e,f; 9a-f). In Phanerozoic sediments, *Botryococcus* alginite remains volatilize during bituminization at the same stage as sporinite reflectance begins to disappear (1.3% R_m) (M. Teichmuller, 1980) and *Tasmanales* alginite leaves no residue or only fine shreds of inertinite when the reflectance of accompanying vitrinite exceeds 1.3% (Stach et al., 1982).

The commonly more deformed and disrupted morphology of lamalginite showing low to no fluorescence suggests that it becomes plastic after most oil has been expelled from it. Vitrinites in the medium- to low-volatile bituminous coal range also appear to undergo a degree of fluidization at appropriate temperatures (Murchison et al., 1985). In beds containing

abundant lamalginite that have at least reached this stage, the lamalginite may flow and coalesce to form matrix bitumen or even veins of bitumen. Matrix bitumen may also be formed from vein bitumen. A bitumen vein in DDH Urapunga 3 in the Velkerri Formation appears to have flowed initially conformably and then across bedding and dispersed into a layer containing abundant matrix bitumen (Plate 29). The presence of oil inclusions in carbonates adjacent to this vein (Plate 29h,i) and strong mineral fluorescence adjacent to some bitumen veins elsewhere (Plate 7g,h) suggest that liquid hydrocarbons flowed through the veins prior to the bitumen or that an early phase asphaltene-rich oil released liquid hydrocarbons, perhaps by the "deasphalting process" (Evans et al., 1971). Deasphalting takes place when normal maturation processes of liquid hydrocarbons produce light paraffins and asphaltenes which cannot coexist in a single liquid phase and results in the separation of the asphaltic components (Silverman, 1971). However, the vein could conceivably have formed from coalesced nonfluorescent lamalginite which initially generated some liquid hydrocarbons.

The origin of the bitumen microspheres is obviously related to the presence of the phosphate microspheres. Both occur only in the Velkerri and Cobanbarini Formations, have the same dimensions (generally less than 10 microns in diameter) and are commonly in close proximity to each other (e.g. Plate 26f). Phosphate microspheres are, in places, imbedded in bitumen (e.g. Plate 34G,H). Bitumen microspheres probably formed, therefore, by the bitumen filling voids previously occupied by phosphate microspheres.

Titaniferous bitumen nodules, less than 200 microns in diameter and found only in one sample from the Barney Creek Formation in the Glyde River Subbasin (Plates 11, 13, and 14), may have formed from oil or bitumen seeping towards the surface. The nodules are within a thin greenish-grey claystone bed approximately 2 cm thick which occurs between grey calcareous siltstones. The claystone formed probably from the devitrification and alteration of a tuff bed. Devitrification and alteration of volcanic particles in this bed probably released titanium from minerals, such as ilmenite, which was then preferentially incorporated by the bitumen. The nodules are rimmed by pyrite and some larger nodules appear to have formed by coalescence of a number of individual nodules rimmed with pyrite. (e.g. Plate 14). The nodules may have formed from oil or bitumen which seeped out subaqueously from the sediments and floated to the surface as small globules. Ash from a volcanic eruption then blanketed the globules and forced them to the bottom. Any ash adhering to the surface of the globules may have included fine-grained pyrite but most of the pyrite associated with the nodules was probably formed as a result of the action of sulphate-reducing bacteria. In some cases, the bitumen or oil globules were almost entirely replaced by pyrite and formed pyritic nodules which, in places, contain oil inclusions (Plate 12).

10.3.4 *Thucholite*

Schidlowski (1969) proposes that thucholite from the Precambrian Witwatersrand system were formed from migrating hydrocarbons condensing and polymerizing around

detrital uraninite through the effects of radiation from the uraninite. Smit (1984) proposes a different origin for thucholite from the Witswatersrand System, suggesting that it formed by growth of microbial organisms around and into uraninite grains resulting in the observed fragmented nature of the uraninite grains. However, polymerization of liquid hydrocarbons seeping into fractures or along cleavage planes of the mineral, could also account for the fragmented nature of the mineral grains.

There is no compelling evidence to suggest that the thucholite in the McArthur Basin formed from growth of microbial organisms around mineral grains as there are no morphological signs that these organisms existed. Further, the observed relatively random occurrence of the thucholite in both fine-grained organic-rich rocks containing lamalginite and in coarser grained units containing virtually no other organic matter, suggests a different origin. The presence of the radioactive mineral, thorite, in the central areas of some large thucholites in the Barney Creek Formation, clearly indicates that the McArthur Basin thucholites formed by accretion of mobile hydrocarbons around radioactive minerals in the manner proposed by Schidlowski (1969).

The presence of noticeable amounts of sulphur in the thucholitic bitumen (Plates 22c and 23c) is not surprising given that sulphur is the third most abundant atomic constituent of crude oils, following hydrogen and carbon (Tissot and Welte, 1978).

CHAPTER 11

SUMMATION AND SIGNIFICANCE TO PETROLEUM AND MINERAL EXPLORATION IN THE PRECAMBRIAN

11.1 Introduction

Organic matter in the middle Proterozoic sequences of the McArthur Basin is contained predominately within fine grained clastic sediments. A number of stratigraphic units contain intervals with TOC greater than 1.0% and two units, the Velkerri and Barney Creek Formations, contain intervals where TOC is up to 7%.

11.2 Organic matter types

The organic matter is made up of a number of petrographically discernable entities:

(1) Fluorescent filamentous-looking organic matter with the filaments generally elongate parallel to bedding, varying in size from several microns to hundreds of microns long by less than 2 microns wide. In many cases, the individual filaments appear to group together to form thicker bodies or strands, which, in places, occur as thin lenticular shapes that are generally less than 0.5 mm long by 0.05 mm thick but, more rarely, are up to several millimetres in length by 1 mm in thickness. In one case, they form apparently continuous mats. In sections cut parallel to bedding, the thin lenticular bodies show an irregular but commonly roughly circular shape. Fluorescence varies from a bright yellow to a dull brownish orange. This type of organic matter occurs in the McMinn, Velkerri and Cobanbarini

Formations of the Roper Group and in the Yalco, Lynott and Barney Creek Formations of the McArthur Group.

This fluorescent organic matter is petrographically identical to a type described from a number of Phanerozoic oil shales by Hutton et al., (1980), Cook et al. (1981), Hutton (1982), Cook and Kantsler (1982), Sherwood and Cook (1984) which initially was called "alginite B" by Hutton et al. (1980) but renamed "lamalginite" by Cook et al. (1982). It can, therefore, with some confidence, be called lamalginite and has been informally referred to here as "fluorescent lamalginite".

(2) Nonfluorescent bands of organic matter which are generally parallel to bedding and vary in size from several microns long by less than two microns wide up to several hundreds of microns long by less than 20 microns wide. In places, they occur with fluorescent bands having a similar morphology or, more rarely, one band may show a gradation along its length from no fluorescence to a dull orange fluorescence.

The nonfluorescent forms are commonly more irregular in thickness than the fluorescent forms. In places, they have a disjointed and partly broken up appearance and, more rarely, form groups, up to several hundreds of microns long, of smaller irregular shapes, less than a few microns in size, which are dispersed along a bedding plane. More rarely again, the nonfluorescent forms are made up of two distinct bands less than 5 microns thick, up to several hundreds of microns long. The nonfluorescent forms, however, do not display the fine laminations observed in the larger bodies of the fluorescent forms. They are, in places, surrounded by a dark nonfluorescent bitumen-impregnated mineral zone. These forms are found in

most of the formations examined with the exception of the Looking Glass Formation, Reward and Emmerugga Dolomites, in the McArthur Group.

These forms are morphologically similar to the fluorescent form and have obviously been derived from it. It has therefore been informally called "nonfluorescent lamalginitite".

(3) Uniformly thin, generally less than 5 microns thick, silvery nonfluorescent organic matter which occurs as single or concentric bands within oncolites; observed in one specimen from the McMinn Formation of the Roper Group. It differs from lamalginitite in that the orientation of the organic matter is not along the bedding plane but follows the morphology of the oncolite. It is therefore referred to informally as "oncalginitite".

(4) Small irregularly shaped bodies of nonfluorescent organic matter, generally less than 10 microns in size, which occur in patches containing several to less than about 50 individual pieces or as discrete individual pieces. In one polished block, isolated bodies of organic matter formed comparatively large cauliflower shapes up to 70 microns across. The boundaries of the patches are generally irregular in shape but, in places, appear as lenticular bodies up to about 50 microns by 30 microns in overall size. With the exception of the large cauliflower forms which occur only in the Velkerri Formation, the other forms are found in the majority of the formations in the McArthur Basin.

The larger pieces are commonly optically non-homogenous under plane-polarised reflected light, particularly the cauliflower shaped forms, and contain zones of lighter or darker reflecting organic matter which, on rotation of the stage, varied in brightness.

These small irregularly shaped bodies of organic matter which occur in patches or as isolated small discrete pieces are similar, apart from the larger cauliflower forms, to particulate pieces of vitrinite or inertinite. However, as no land plants had evolved by the time the McArthur Basin was formed, it is clearly unsuitable to refer to them as vitrinite or inertinite. Their irregular morphology is consistent with descriptions given of bitumen in Phanerozoic sediments by Jacob ((1976, 1981) who considers bitumen's most important characteristic is the variety of its morphological form. This organic matter is therefore called bitumen. Patches of bitumen are informally referred to as "patchy dispersed bitumen", the small isolated and discrete grains of bitumen as "disseminated bitumen" and the larger cauliflower forms as "cauliflower bitumen".

(5) More massive organic matter than (4) which is generally optically homogenous and surrounds mineral grains forming an organic matrix. This type of organic matter forms an organic mass containing "imbedded" mineral grains, and has irregular dimensions which are generally less than 100 microns in size but, in places, can be much larger. It is generally nonfluorescent but does display in rare cases, a dull orange fluorescence. It occurs in the McMinn, Velkerri and Mainoru Formations of the Roper Group, in the Balbarini Dolomite of the Nathan Group and in the Reward Dolomite, Lynott and Barney Creek Formations of the McArthur Group.

The variety of its morphological form clearly identifies it as bitumen and as it forms a matrix to mineral matter it is called "matrix bitumen".

(6) Bitumen veins which crosscut or are conformable to bedding. The width of the veins vary from a few microns to up to several hundreds of microns. They occur in the majority of formations in the McArthur Basin. The veins are, in places, optically non-homogeneous, either displaying variably shaped optically homogenous zones of varying brightness, or alternating dark and brightly reflecting laminae.

(7) Vug bitumen that appears to fill pre-existing spaces, or vugs, in the rock fabric. They vary in size from less than 20 microns to in excess of 50 microns. They occur in carbonates of the McArthur Group within the Looking Glass Formation and the Reward and Emmerugga Dolomites. Very few examples of this type of organic matter were observed and no reflectance measurements were made.

(8) Round grains of organic matter up to 0.5 mm in diameter, which in handspecimens appear black but under the microscope have a silvery surface, and commonly have noticeably higher reflecting central areas. In some cases the peripheral organic matter displays a weak orange fluorescence. Some grains have mineral cores which, in some cases, is the mineral thorite. Reflectances generally increase exponentially towards the center of these grains and they are optically markedly anisotropic. This organic matter is called "thucholite" as it is identical to thucholites described by Cook and Kantsler (1982) from Australian sedimentary rocks ranging in age from the Precambrian to the Mesozoic.

(9) Microspheres of nonfluorescent organic matter, less than 10 microns in diameter, which show no obvious increase in reflectance towards their centers and are associated with

phosphate microspheres having the same dimensions, in the Velkerri and Cobanbarini Formations of the Roper Group. This organic matter has probably occupied spaces formerly occupied by the phosphate microspheres, and could therefore be termed vug bitumen. However because it has a clearly defined morphology, although an assumed morphology, it is called bitumen microspheres.

11.3 Origin of the Organic Matter

Previous micropalaeontological studies have revealed an extensive microbiota consisting of unicellular, colonial and filamentous forms preserved in cherts, carbonates, and fine grained clastic sediments in the McArthur Basin. The contribution these micro-organisms made to the formation of lamalginites was probably significant and included small colonial forms in the case of lamalginites in the Barney Creek Formation, and small to large unicell forms in lamalginites from the Roper Group. Microbial organisms, possibly cyanobacteria, also formed the source biota for oncolites. The remains of most micro-organisms have been rendered unrecognisable by the effects of bacterial degradation (particularly by sulphate reducers, who are also probably included in the preserved biomass), compaction and diagenesis.

With increasing maturation, fluorescence in lamalginites diminishes and eventually ceases. Nonfluorescent lamalginites commonly exhibit a more deformed and disrupted morphology than fluorescent lamalginites. Fine lamellae, observed in the larger bodies of fluorescent lamalginites, are absent. Disaggregation of nonfluorescent lamalginites, possibly related to

hydrocarbon generation, may have led to the formation of patchy dispersed bitumen or disseminated bitumen. If sufficient nonfluorescent lamalginite was present it may have coalesced to produce matrix or vein bitumen.

11.4 Reflectances of the Organic Matter Types

Reflectances of fluorescent lamalginite are generally lower than the other types of organic matter. Mean maximum reflectances range from 0.05 to 0.53%. It is optically slightly anisotropic but shows a systematic increase in anisotropy with increasing reflectance. Where fluorescent lamalginite, nonfluorescent lamalginite and/or bitumen are present in the same polished block, the reflectance of fluorescent lamalginite is about half that of the other types.

Mean maximum reflectances of nonfluorescent lamalginite range from 0.42 to 4.27% and for bitumen they range from 0.44 to 5.39%. Nonfluorescent lamalginite and bitumen are optically anisotropic which at low levels of reflectance is not marked but at high reflectances is quite marked.

11.5 Assessment of Maturation Levels

The advantage of using reflectance and Tmax indices over other maturation indices is that they are relatively quick and easy to obtain. Assessing maturation levels by the colour of organic matter in strew mounts or thin sections requires more preparation and the results are qualitative. Molecular maturation indices, such as the MPI-1, require the most effort and are difficult to obtain in the overmature zone due to low yields of extractable hydrocarbons. An additional problem, in the case of

the MPI-1 index, is that, at high temperatures, demethylation reactions lead to a lowering of the index. Tmax indices are also similarly difficult to obtain from overmature organic matter as most hydrocarbon has already been cracked from the kerogen. Tmax results are also unreliable in samples containing low amounts of organic matter. Both Tmax and molecular maturation indices are affected by migrated oil. Reflectances, on the other hand, can be obtained from samples containing low amounts or overmature organic matter and also from partly weathered samples unsuitable for geochemical analyses. Rock-Eval analyses are comparatively quick and easy to do whereas obtaining reflectance measurements requires a larger sample, more sample preparation, and a degree of cognitive and manipulative skill. Both indices, however, required calibration with respect to the oil generative window in the Precambrian to be of any use.

In the McArthur Basin, Tmax values between 425 and 470° C and maximum reflectances between 0.15% for fluorescent lamalginite and 1.4% for nonfluorescent lamalginite and/or bitumen, are within the oil window. Reflectances of fluorescent lamalginite are depressed by about 0.4 to 0.5% with respect to vitrinite reflectances calculated from methylphenanthrene indices. Maximum reflectances of nonfluorescent lamalginite and/or bitumen are similar to vitrinite reflectances calculated from methylphenanthrene indices.

Fluorescent lamalginite is present only from the start to the middle zone of the oil window whereas nonfluorescent lamalginite and/or bitumen occurs only from the middle zone to the base of the oil window. The reduction and eventual loss of fluorescence in lamalginite is clearly associated with

hydrocarbon generation. Maturation levels of specimens containing both fluorescent and nonfluorescent lamalginite are variable and range across the middle zone of the oil window. The differing fluorescing characteristics at the same maturation levels may be attributable to variations in the chemical composition and source biota of the lamalginite.

Levels of maturation as measured by reflectance and Tmax generally show a systematic increase with increasing depth in individual drill holes showing that maturation processes that produce such changes in the Phanerozoic produce similar changes in the Precambrian. Reflectances were obtained on a number of samples which produced unreliable results from Rock-Eval pyrolyses due to low TOC, migrated hydrocarbons or overmature organic matter. They therefore proved to be a far more useful measure of maturation levels in the basin.

11.6 Maturation Patterns and History of the McArthur Basin.

Organic matter in the Maiwok Subgroup of the Roper Group is marginally mature to mature but in places is overmature as a result of contact metamorphism adjacent to dolerite sills. Maturation levels in the lower Roper Group are at least marginally overmature. Maturation levels that have not been affected by contact metamorphism increase with the age of formations in the Roper Group and are fairly similar for the same formation over a wide areal extent. Such a pattern is consistent with the concept that the Roper Group formed during the sag phase of the basin's development and that there has been subsequently a relatively uniform geological history. The

localized zones of contact metamorphism were probably superimposed upon the regional pattern but it is possible that at least in part, the contact alteration predates much of the regional rank change, the evidence being, however, equivocal.

Maturation levels in the Nathan and McArthur Groups range from being at least marginally immature to overmature. Hydrothermal activity, producing localised zones of increased temperatures, and, in places associated with base-metal mineralisation, have affected some maturation levels in a manner similar to contact metamorphism. Maturation levels, unaffected by hydrothermal activity, show considerable overlap between formations. Such a pattern probably resulted from variable subsidence rates and geothermal gradients during the final phase of extension in the basin which preceded the sag phase.

Modelled maturation levels based on reconstructions of the geological history of the basin and using two methods, the Lopatin (1971) method as modified by Waples (1980) and Price's (1983) method, are compared with observed reflectances recalculated to vitrinite reflectances. The Lopatin-Waples method assumes that time and temperature are factors in the maturation process, provides the best fit between modelled and observed recalculated reflectances in the Roper Group. By contrast, Price's (1983) method assumes that the maximum temperature experienced by organic matter is the only factor.

Time is therefore an important factor in the maturation of organic matter unaffected by contact metamorphism in the Roper Group and by extension, for all organic matter in the basin which has not experienced high temperatures. The modelling results for

the Roper Group, using the Lopatin-Waples method, suggest that it was up to about 1000 m thicker than its observed maximum thickness. The modelling results for the Barney Creek Formation in the Glyde River Subbasin, using the Lopatin-Waples method, indicate that the sedimentary cover overlying this subbasin was never greater than about 2000 m.

11.7 Timing of oil generation

The timing of oil generation within the two formations containing the most organic matter in the basin (Barney Creek and Velkerri Formations), based on the Lopatin-Waples method, indicates that the onset and peak oil generation, from the base of these formations occurred before about 1400 Ma for the Barney Creek Formation and before about 1000 Ma for the Velkerri Formation. However, the start and peaking of oil production for sections above the base of these formations occurred later and in the case of the uppermost section of the Barney Creek Formation in the Glyde River Basin, it has never reached peak oil production. If geothermal gradients in the past were much the same as observed today (30 C°/km), and there is some evidence to suggest this is the case since deposition of the Roper Group, then temperatures at the base of both formations have been less than 70° C since about 1000 Ma in the case of the Velkerri Formation and since about 1400 Ma for the Barney Creek Formation. Oil generation virtually ceases at temperatures below about 50 - 70° C (Gretener and Curtis, 1982) but may proceed at very slow rates due to the quantum mechanical tunnelling effect (Snowdon, 1979). Hydrocarbons may therefore have been generated, albeit at

very slow rates, for a considerable period extending well into the Phanerozoic.

11.8 Significance for petroleum and mineral exploration

Exploration for petroleum in Precambrian basins is considered a high risk venture and fraught with problems. One of the major problems is that organic matter in such basins is commonly overmature or thought to be overmature due to the antiquity of the basins. The commonly used maturation indices, reflectance and Tmax, developed from studies in Phanerozoic basins, may be misleading and no research had previously been undertaken in an attempt to establish their reliability or ranges with respect to the oil window in Precambrian basins. This study has established that both reflectance and Tmax indices can be used successfully and has defined their ranges with respect to the oil-window in the McArthur Basin. It is probable that the oil-window for organic matter in other Precambrian basins will be broadly the same with respect to these indices given the relative lack of diversity in Precambrian biota with respect to Phanerozoic biota.

This study has also demonstrated that oil and gas, which were generated from a number of organic rich units in the McArthur Basin, would not have become thermally degraded in certain areas. Economic accumulations of hydrocarbons could occur in the upper part of the Roper Group which is present over broad areas of the basin, and within smaller areas containing McArthur and Nathan Group sediments where the organic matter in them is not significantly overmature.

The observation that anomalously high maturation levels of organic matter in the McArthur Group are probably caused by hydrothermal activity, which, in places, is associated with base metal mineralisation such as the large H.Y.C. deposit, could help in the search for similar ore-bodies in the McArthur Basin and in other Precambrian basins. An anomalously high maturation level in a barren mineral exploration drill hole, may indicate a nearby ore body.

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**PETROLOGICAL AND MATURATION CHARACTERISTICS OF
ORGANIC MATTER FROM THE MIDDLE PROTEROZOIC McARTHUR
BASIN, AUSTRALIA.**

VOLUME 2

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for the award of the degree of

DOCTOR OF PHILOSOPHY

from

THE UNIVERSITY OF WOLLONGONG

by

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DDH/Fm.	depth (m)	1:250,000 sheet	lat. long.	1:100,000 sheet	grid ref.
GR1 (Amoco)		Bauhinia Downs	16°53', 136°15'	Glyde	332320
Bukalara Sst.	0 - 13.6				
Barney Creek Fm.	13.6 - 359.0	T.D.			
GR2 (Amoco)		Bauhinia Doowns	16°56', 136°17'	Glyde	366275
Bukalara Sst.	0 - 45.5				
Barney Creek Fm.	45.5 - 239.0	T.D.			
GR3 (Amoco)		Bauhinia Downs	16°52', 136°14'	Glyde	317333
Bukalara Sst.	0 - 14.2				
Barney Creek Fm.	14.2 - 458.0				
Coxco Dolomite	458.0 - 509.0	T.D.			
GR4 (Amoco)		Bauhinia Downs	16°59', 136°18'	Glyde	385204
Bukalara Sst.	0 - 89.0				
Barney Creek Fm.	89.0 - 208.0				
Coxco Dolomite	208.0 - 275.0	T.D.			
GR5 (Amoco/Kennecott)		Bauhinia Downs	16°53', 136°17'	Glyde	362319
Bukalara Sst.	0 - 23.0				
Reward Dolomite	23.0 - 41.5				
Barney Creek Fm.	41.5 - 512.7	T.D.			
GR6 (Amoco)		Bauhinia Downs	16°54', 136°28'	Glyde	318579
McArthur or Tawallah Group (uncertain)	0 - 194.0	T.D.			
GR7 (Amoco/Kennecott)		Bauhinia Downs	16°54', 136°18'	Glyde	385306
Bukalara Sst.	0 - 34.2				
Barney Creek Fm.	34.2 - 917.0	T.D.			
GR8 (Kennecott)		Bauhinia Doowns	16°59', 136°20'	Glyde	418206
Bukalara Sst.	0 - 10.2				
Barney Creek Fm.	10.2 - 613.0	T.D.			
GR9 (Kennecott)		Bauhinia Downs	16°58', 136°19'	Glyde	402238
Bukalara Sst.	0 - 42.5				
Barney Creek Fm.	42.5 - 501.8				
Coxco Dolomite	501.76 - 534.0	T.D.			
GR10 (Shell)		Bauhinia Downs	16°56', 136°18'	Glyde	392277
Bukalara Sst.	0 - 12.0				
Barney Creek Fm.	12.0 - 699.1				
Coxco Dolomite	699.1 - 704.0	T.D.			
GR11 (Shell)		Wallhallow	17°02', 136°21'	Lancewood	426174
Bukalara Sst.	0 - 10.5				
Barney Creek Fm.	10.5 - 451.0				
Coxco Dolomite	451.0 - 470.0	T.D.			

APPENDIX A. Locations and stratigraphy of drill holes GR1 - 11, McArthur Group, Glyde River Subbasin.

DDH/Fm.	depth(m)	1:250,000 sheet	lat.	long.	1:100,000 sheet	grid ref.
BJ1 (A.O.(Aust.) Pty. Ltd./Shell)		Bauhinia Downs	16°25',	135°56'	Batten	001835
Lynott Fm.	0 - 27.0					
?Reward Dolomite	27.0 - 28.0					
Barney Creek Fm.	28.0 - 53.0					
Coxco Dolomite	53.0 - 101.0	T.D.				
BB2 (Shell)		Mount Young	15°48',	135°58'	Tawallah Range	042533
Lynott Fm.	0 - 35					
Reward Dolomite	35 - 255					
Barney Creek Fm.	255 - 420					
Teena Dolomite	420 - 443	T.D.				
BB5 (Shell)		Mount Young	15°47',	136°03'	Bing Bong	108539
Lynott Fm.	0 - 65					
Reward Dolomite	65 - 220					
Barney Creek Fm.	220 - 350					
Teena Dolomite	350 - 370	T.D.				
BJ3 (A.O.(Aust) Pty. Ltd./Shell)		Bauhinia Downs	16°26',	135°26'	Batten	991842
Lynott Fm.	0 - 4.7					
?Reward Dolomite	54.7 - 57.7					
Barney Creek Fm.	57.7 - 135.0					
Coxco Dolomite	135.0 - 151.5	T.D.				
BJ6 (A.O.(Aust) Pty. Ltd./Shell)		Bauhinia Downs	16°24',	135°53'	Batten	933865
Lynott Fm.	0 - 204.0	T.D.				
CA 1 (C.R.A.E., Amoco)		Bauhinia Downs	16°18',	136°05'	Borrooloola	149977
Lynott Fm.	0 - 200					
Reward Dolomite	200 - 300					
Barney Creek Fm.	300 - 610	TD				
CA 2 (C.R.A.E., Amoco)		Bauhinia Downs	16°17',	136°04'	Borrooloola	139995
Lynott Fm.	0 - 166					
Reward Dolomite	166 - 479					
Barney Creek Fm.	479 - 632					
Coxco Dolomite	632 - 688	TD				
CA 3 (C.R.A.E., Amoco)		Bauhinia Downs	16°18',	136°04'	Borrooloola	139978
Lynott Fm.	0 - 189					
Reward Dolomite	189 - 405					
Barney Creek Fm.	405 - 567					
Cooley Dolomite	567 - 718	TD				

APPENDIX A ctd. Locations and stratigraphy of drill holes (BJ-1 - CA3) Nathan and McArthur Groups, central and northern Batten Trough

DDH/Fm.	depth(m)	1:250,000 sheet	lat. long.	1:100,000 sheet	grid ref.
Leila Yard 1		Bauhinia Downs	16°37', 135°52'	Mallapunya	925634
Lynott Fm.	0 - 364.05				
Reward Dolomite	364.05 - 369.02				
Surprise Creek Dol.	369.02 - 377.82				
Barney Creek Fm.	377.82 - 515.90				
Teena Dolomite	515.90 - 527.00	T.D.			
MANT-79-3 (Amoco)		Bauhinia Downs	16°18', 136°05'	Borroloola	150978
Lynott Fm.	0 - 200				
Reward Dolomite	200 - 300				
Barney Creek Fm.	300 - 485	T.D.			
McA 5 (B.H.P)		Mount Young	15°56', 136°04'	Bing Bong	140390
Barney Creek Fm.	0 - 405.5		location approximate, within 5 km.		
Teena Dolomite	405.5 - 452.5				
Emmerugga Dolomite	452.5 - 496.0	T.D.			
McA 6 (B.H.P.)		Bauhinia Downs	16°01', 135°32'	Batten	581289
Mainoru Fm.	0 - 150				
Limmen Sst.	150 - 171				
Mantungula Fm.	171 - 273				
Tooganinie Fm.	273 - 400	T.D.			
McA10 (B.H.P)		Bauhinia Downs	16°31', 135°58'	Mallapunya	030740
Barney Creek Fm.	0 - 100		location approximate, within 5 km.		
Teena Dolomite	100 - 150				
Emmerugga Dolomite	150 - 365	T.D.			
Mariner D1 (B.H.P)		Bauhinia Downs	16°04', 135°34'	Batten	600230
?lower McArthur Gp.	0 - 150		location approximate, within 2km.		
MY5		Bauhinia Downs	16°36', 136°03'	Glyde	118652
(Shell, A.O.(Aust.)Pty. Ltd.)					
Reward Dolomite	0 - 136.07				
Surprise Creek Dol.	136.07 - 193.70				
Barney Creek Fm.	193.70 - 369.20				
Teena Dolomite	369.20 - 387.30	T.D.			

APPENDIX A ctd. Locations and stratigraphy of drill holes (Leila Yard 1 - MY5), Nathan and McArthur Groups, central and northern Batten Trough.

DDH/Fm.	depth(m)	1:250,000 sheet	lat.	long.	1:100,000 sheet	grid ref.
WM6 (Shell, A.O.(Aust.)Pty. Ltd.) Lynott Fm. Reward Dolomite Barney Creek Fm.	 0 - 42.00 42.00 - 91.63 91.63 - 543.00	Mount Young T.D.	15°35',	135°55'	Tawallah Range	979775
8 2 / 4 Balbarini Dolomite unspec McA. Gp.	 0 - 222 222 - 541	Mount Young TD	15°30',	135°07'	Towns	130867
8 2 / 5 Donnegan Member Hot Spring Member (Lynott Fm.)	 0 - 45 45 - 455	Bauhinia Downs TD	16°23',	135°58'	Batten	037062
8 2 / 6 Looking Glass Fm. Stretton Sandstone Yalco Formation Lynott Formation	 0 - 23 23 - 42 42 - 266 266 - 300	Bauhinia Downs TD	16°43',	136°14'	Glyde	319527
8 2 / 7 Balbarini Dolomite Looking Glass Fm. Stretton Sandstone Yalco Formation Lynott Formation	 0 - 54.7 54.7 - 81.0 81.0 - 116 116 - 269 269 - 464	Bauhinia Downs TD	16°46',	136°00'	Mallapunyah	6064445

APPENDIX A ctd. Locations and stratigraphy of drill holes (WM6 - 82/7), Nathan and McArthur Groups, central and northern Batten Trough.

DDH/Fm.	depth(m)	1:250,000 sheet	lat.	long.	1:100,000 sheet	grid ref.
Broadmere 1		Bauhinia Downs	16°28'	135°18'	Bauhinia Downs	343948
Cobanbarini Fm	0 - 452					
Bessie Ck. Sst.	452 - 817					
Corcoran Fm.	817 - 972					
dolerite sill	972 - 1146					
Corcoran Fm.	1146 - 1298					
Hodgson Sst. Mbr.	1298 - 1592					
Jalboi Mbr.	1298 - 1648					
Arnold Sst. Mbr.	1648 - 1927					
Crawford Fm.	1927 - 2067					
Mainoru Fm.	2067 - 2174	TD				
B8 (BHP, 1958)		Urapunga	14°44'	134°20'	Chapman	Na
McMinn Fm.	0 - 70					
KRATOS 11 (Kratos)		Bauhinia Downs	13°26'	135°11'	Bauhinia Downs	832202
Bessie Creek Sst.	0 - 6.5					
Corcoran Fm.	6.5 - 65.4					
dolerite sill	65.4 - 115.9					
Corcoran Fm.	115.9 - 401.4					
Hodgson Sst.	401.4 - 405.5	T.D.				
Urapunga 1 (BMR)		Urapunga	14°10'	133°51'	Flying Fox	742314
Mainoru Fm.	0 - 269					
Limmen Sst.	269 - 269.2	TD				
Urapunga 2 (BMR)		Urapunga	14°55'	133°38'	Moroak	522509
Corcoran Fm.	0 - 84					
dolerite sill	84 - 94	TD				
Urapunga 3 (BMR)		Urapunga	14°39'	133°44'	Moroak	650797
Velkerri Fm.	0 - 211	TD				
Urapunga 4 (BMR)		Urapunga	14°32'	134°17'	Chapman	237742
McMinn Fm	0 - 42					
Velkerri Fm.	42 - 372.5					
Bessie Ck. Sst.	372.5 - 397.6					
Corcoran Fm.	397.6 - 532	TD				

APPENDIX B. Location and stratigraphy of drill holes
(Broadmere 1 - Urapunga 4) in the Roper Group

DDH/Fm.	depth(m)	1:250,000 sheet	lat.	long.	1:100,000 sheet	grid	ref.
Urapunga 5 (BMR)		Urapunga	14°43',	134°25'	Chapman	373734	
Munyi Mbr.	0 - 34.7						
Hodgson Sst. Mbr.	34.7 - 112.5						
Jalboi Mbr.	112.5 - 284						
dolerite sill	198 - 271						
Arnold Mbr.	284 - 327						
Crawford Fm.	327 - 391						
Mainoru Fm.	391 - 604.1	TD					
Urapunga 6 (BMR)		Urapunga	14°44',	134°22'	Urapunga	499702	
Mainoru Fm.	0 - 312						
Limmen Sst.	312 - 414.5						
"Mantungula Fm."	414.5 - 422.8	TD					
X28 (BHP, 1958)		Urapunga	15 °11',	133°50'	Mais	Na	
McMinn Fm.	0 - 83						
82/1 (Amoco)		Bauhinia Downs	16°10',	135°18'	Bauhinia Downs	321133	
"Crooked Ck. Lmst.	0 - 25						
"Cat Ck. Member"	25 - 222						
"Broadmere Sst. Mbr."	222 - 376						
"Lansen Ck. Shale"	376 - 579	TD					
82/2 (Amoco)		Mount Young	15°59',	135°21'	Mantungula	353318	
Mainoru Fm.	0 - 161						
Limmen Sst	161 - 205						
Fault repeat of above.	205 - 430						
"Mantungula Fm."	430 - 494	TD					
82/3 (Amoco)		Mount Young	15°44',	135°16'	Mantungula	285605	
Hodgson Mbr.	0 - 144.9						
Jalboi Mbr.	144.9 - 243.3						
Arnold Mbr.	243.3 - 287.1						
Crawford Fm.	287.1 - 459.0						
Mainoru Fm.	459.0 - 592	TD					
82/8 (Amoco)		Bauhinia Downs	16°41',	135°49'	Mallapunyah	880553	
Velkerri Fm.	0 - 103						
Bessie Ck. Sst.	103 - 221	TD					

APPENDIX B ctd. Location and stratigraphy of drill holes
(Urapunga 5 - 82/8) in the Roper Group.

DDH/Fm.	Depth(m)	Lithology	Organic matter types
GR 1			
Barney Ck. Fm.	26.5	dark grey calcilutite	lam., thuch.
	92.2	dark grey calcilutite	lam., thuch.
	279.5	light grey to dark grey banded calcilutite	lam., thuch.
	320.2	dark grey calcilutite	d.b., nf. lam., thuch.
GR 2			
Barney Ck. Fm.	62.9	dark grey calcilutite	lam., thuch.
	180.5	grey calcilutite grading into fine calcarenite	lam., thuch.
	238.2	dark grey calcilutite	lam., nf. lam., p.d.b., thuch.
GR 3			
Barney Ck. Fm.	30.1	dark grey calcilutite	lam., thuch.
	162.8	dark grey calcilutite	lam., thuch.
	302.6	dark grey calcilutite	lam., p.d.b., v.b., m.b., thuch.
GR 4			
Barney Ck. Fm.	107.7	laminated light and dark grey calcilutite	lam., thuch.
	129.5	laminated light and dark grey calcilutite, carbonate veins	lam., nf. lam., p.d.b., thuch.
	151.4	laminated light and dark grey calcilutite	p.d.b., nf. lam., lam.
	162.6	laminated off-white and black calcilutite	p.d.b., d.b., v.b.
GR 5			
Barney Ck. Fm.	72.5	dark grey calcilutite grading into fine calcarenite	lam., thuch.
	150.0	dark grey calcilutite	lam., thuch.
	306.3	dark grey calcilutite	lam., nf. lam., p.d.b., d.b., thuch.
	426.0	laminated light and dark grey calcilutite	d.b., nf. lam., lam., p.d.b., thuch.
	494.8	dark grey calcilutite	lam., nf. lam., d.b., p.d.b., thuch.
GR7			
Barney Ck. Fm.	38.7	dark grey calcilutite	lam., thuch.
	50.3	dark grey calcilutite	lam., thuch.
	180.0	dark grey calcilutite containing thin phosphate laminae	lam., thuch.
	238.8	dark grey calcilutite	lam., thuch.
	426.7	dark grey calcilutite	lam., thuch.
	601.5	dark grey calcilutite grading into very fine calcarenite	lam., nf. lam., p.d.b., thuch.
	794.6	dark grey calcilutite, minor thin carbonate veins	p.d.b., thuch.
	854.0	dark grey calcilutite	p.d.b., thuch.

ABBREVIATIONS

lam. = fluorescent lamalginite;
 nf. lam. = nonfluorescent lamalginite;
 p.d.b. = patchy dispersed bitumen; d.b. = disseminated bitumen;
 v.b. = vein bitumen; m.b. = matrix bitumen; vg.b. = vug bitumen
 thuch = thucholite;

APPENDIX C. Rock and organic matter types, Nathan and McArthur Groups, DDH's GR1 - 7.

DDH/Fm.	Depth(m)	Lithology	Organic matter types
GR 8			
Barney Ck. Fm.	49.2	dark grey calcilutite grading into fine calcarenite	lam., thuch.
	250.4	laminated light grey and dark grey calcilutite	lam., thuch.
	349.3	dark grey calcilutite	lam., nf. lam., d.b., p.d.b., thuch.
	451.0	dark grey calcilutite	nf. lam., p.d.b., d.b., thuch.
	570.8	dark grey calcilutite	nf. lam., p.d.b., d.b., thuch.
GR 9			
Barney Ck. Fm.	79.1	dark grey calcilutite	lam., thuch.
	337.8	dark grey calcilutite grading into fine calcarenite	lam., thuch.
	422.2	dark grey calcilutite	lam., nf. lam., p.d.b., thuch.
	500.1	dark grey calcilutite	nf. lam., p.d.b., d.b., thuch.
GR 10			
Barney Ck. Fm.	23.2	dark grey calcilutite	lam., thuch
	37.4	laminated, grey calcilutite grading into fine calcarenite, with greenish-grey tuffaceous laminae	lam., thuch., titaniferous bitumen
	88.4	dark grey calcilutite	lam., thuch.
	92.6	very fine carbonate pebble ($\leq 4\text{mm}$) conglom., black lutite bed	lam, thuch
	133.8	dark grey calcilutite	lam., thuch
	137.3	dark grey calcilutite grading into fine calcarenite	lam.
	141.9	dark grey calcilutite	lam., thuch.
	143.3	dark grey calcilutite	lam., thuch.
	146.4	dark grey calcilutite grading into fine calcarenite	lam., thuch
	155.2	dark grey calcilutite grading to very fine carbonate($\leq 4\text{mm}$) conglom.	lam., thuch
	170.3	very fine calcarenite	lam., thuch.
	232.8	dark grey calcilutite	lam., thuch.
	297.2	dark grey calcilutite	lam., thuch.
	304.4	grey calcilutite grading into light grey fine calcarenite	lam. ,thuch
	410.0	dark grey calcilutite grading into fine calcarenite	lam., thuch.
	443.0	grey calcilutite, trace glauconite	lam., nf. lam.,v.b., p.d.b., d.b., thuch.
	514.2	dark grey calcilutite	lam., thuch.
	575.3	laminated, grey calcilutite grading into fine calcarenite	lam., nf. lam., d.b., p.d.b., thuch.
	602.5	dark grey calcilutite	nf. lam., p.d.b., thuch.
	646.9	dark grey calcilutite	v.b.
	662.1	calcilutite grading into fine calcarenite	v.b.

DDH/Fm.	Depth(m)	Lithology	Organic matter types
GR 11			
Barney Ck. Fm.	96.9	dark grey calcilutite	lam., thuch.
	202.8	dark grey calcilutite	lam., nf. lam., p.d.b., thuch.
	258.7	dark grey calcilutite, 200 μ band of sphalerite	nf. lam., p.d.b., thuch.
	347.4	dark grey calcilutite	nf. lam., p.d.b., thuch.
	415.2	dark grey calcilutite	p.d.b., thuch.
	442.0	dark grey calcilutite	nf. lam., p.d.b., thuch.
BB2			
Reward Dolomite	72.0	dark grey, very fine calcarenite, fine pyritic carbonate veins	vg. b., d.b., p.d.b., thuch.
Barney Ck. Fm.	273.3	dark grey, very fine calcarenite	p.d.b., thuch.
	374.0	dark grey, very fine, pyrite veined, calcarenite	m.b.
BB5			
Reward Dolomite	70.0	dark grey lutite	thuch.
	177.9	dark grey lutite	thuch.
Barney Ck. Fm.	249.2	dark grey calcilutite	nf. lam., d.b., thuch.
BJ1			
Lynott Fm.	10.2	light to dark grey, very fine calcarenite	p.d.b., thuch.
Barney Ck. Fm.	30.6	dark grey, very fine calcarenite	p.d.b., thuch.
Coxco Dolomite	95.2	off-white to dark-grey very fine calcarenite	p.d.b., v.b.
CA1			
Reward Dol.	253.7	dark grey calcilutite	d.b., v.b., thuch.
Barney Ck. Fm.	337.6	dark grey calcilutite	nf. lam., p.d.b.
CA3			
Barney Ck. Fm.	481.4	dark grey calcilutite, thin laminae of pyrite, cross-cutting carbonate-bitumen vein	v.b., d.b.
Lella Yard 1			
Lynott Fm.	21.4	light to dark grey calcilutite	nf. lam., p.d.b.
	156.8	dark grey, very fine arenite	p.d.b.
	271.4	dark grey, very fine arenite	nf. lam., p.d.b.
Barney Ck. Fm.	408.5	dark grey, very fine arenite	p.d.b., d.b.
	500.0	dark grey, very fine arenite	p.d.b., d.b.
MANT 79-3			
Lynott Fm.	24.2	dark grey very fine arenite	nil
	151.2	dark grey lutite	pyritised lam.
Reward Dolomite	279.8	dark grey calcilutite, small cross-cutting pyrite-bitumen-carbonate veins	v.b., p.d.b.
Barney Ck. Fm.	349.8	dark grey calcilutite	nf. lam., p.d.b.

APPENDIX C ctd. Rock and organic matter types, Nathan and McArthur Groups, Glyde River Subbasin, DDH GR11, and central and northern Batten Trough (DDH's BB2 - MANT 79-3)

DDH/Fm.	Depth(m)	Lithology	Organic matter types
McA 5			
Barney Ck. Fm.	59.4	dark grey calcilutite, small oxidised fracture	nf. lam., p.d.b., thuch.
	74.0	dark grey, very fine calcarenite	nf. lam., p.d.b., d.b., thuch.
	138.2	light to dark grey, very fine calcarenite	nf. lam., p.d.b., d.b., thuch.
	265.0	dark grey calcilutite	thuch.
	306.4	dark grey, very fine calcarenite	nf. lam., p.d.b., thuch.
	357.4	dark grey, very fine calcarenite	nf. lam., d.b., thuch.
Teena Dolomite	441.4	light-grey calcilutite separated from silicified banded carbonate by a stylolite	v.b.
McA. 10			
Barney Ck. Fm.	27.8	dark grey calcilutite	nf. lam., d.b., p.d.b., thuch.
Teena Dolomite	139.3	dark grey calcilutite, numerous py-carbonate,py-sphal. veinlets	nf. lam., p.d.b., thuch.
Emmerugga Dol.	160.7	light to dark grey calcilutite, cross-cutting carbonate-bitumen vein	v.b., d.b., vg.b.
	243.1	light to dark grey calcilutite to very fine calcarenite	v.b., vg.b.
MY5			
Reward Dol.	67.2	silicified, veined, carbonate	v.b.
Barney Ck. Fm.	288.0	dark grey, very fine calcarenite	p.d.b.
	330.7	dark grey calcilutite, sphalerite microveins	p.d.b., nf. lam., thuch.
M 17 / 0 8			
Barney Ck. Fm.	112.0	dark grey calcilutite, with pyrite-rich laminae	nf. lam., p.d.b., d.b., m.b., v.b., thuch.
	339.5	dark grey calcilutite, with pyrite-rich laminae, and irregular veins and patches of carbonate-sphalerite-galena	p.d.b., d.b.
	351.4	dark grey lutite grading into medium grained arenite	nf. lam., v.b., d.b.
N 27 / 6 3			
Barney Ck. Fm.	31.7	dark grey lutite, small band of calcilutite	nf. lam., p.d.b., d.b.
	105.5	dark grey, very fine grained calcarenite, pyrite rich laminae	p.d.b., d.b., v.b.
	172.8	dark grey calcilutite, with pyrite or sphalerite rich laminae, grading into medium grained calcarenite	v.b.
	313.0	dark grey lutite with numerous sphalerite/galena or pyrite laminae	nf. lam., p.d.b., d.b.
	335.0	dark grey lutite with numerous sphalerite/galena or pyrite laminae	d.b.
	380.9	grey calcilutite with fine greenish-grey bands	d.b.,p.d.b.
	388.9	irregularly banded carbonate, with network veins of pyrite, bitumen and sphalerite	v.b.

APPENDIX C ctd. Rock and organic matter types, Nathan and McArthur Groups, central and northern Batten Trough (DDH's McA5 - N27/63)

DDH/Fm.	Depth(m)	Lithology	Organic matter types
WM6			
Barney Ck. Fm.	200.8	dark grey calcilutite	d.b., thuch.
	423.6	dark grey calcilutite	nf. lam., d.b., thuch.
	519.3	dark grey calcilutite	d.b., thuch.
82 / 4			
Balbarini Dol.	61.8	calcilutite breccia	d.b.
	84.2	laminated grey to dark grey calcilutite	nf. lam., p.d.b.
unspec. McA. Gp.	468.7	dark grey calcilutite	nf. lam., d.b., p.d.b.
82 / 5			
Lynott Fm.	54.7	dark grey calcilutite	p.d.b., d.b.
	191.7	laminae of very fine grained light grey arenite and dark grey lutite	v.b., p.d.b.
	453.6	dark grey very fine grained arenite with cross cutting carbonate veins	p.d.b.
82 / 6			
Yalco Fm.	125.7	laminae of very fine grained light grey arenite and dark grey lutite, patches of pyrite.	lam.
Lynott Fm.	290.3	light-grey lutite with dark-grey laminations, irregular lenses of very fine grained arenite.	lam., thuch.
82 / 7			
Looking Glass Fm.	55.5	very fine grained calcarenite with chalcedony patches	v.b., vg.b.
Yalco Fm.	186.3	dark-grey lutite	lam., nf. lam., v.b., m.b., thuch.
	327.5	carbonate breccia	v.b.

APPENDIX C ctd. Rock and organic matter types, Nathan and McArthur Groups, central and northern Batten Trough (DDH's WM6 - 82/7).

DDH/Fm.	Depth(m)	Lithology	Organic matter types
Broadmere 1			
Cobanbirini Fm.	27.4	dark grey siltstone	lam., nf. lam.
	109.7	dark grey siltstone	lam.,nf. lam., p.d.b., b.m.
	155.4	dark grey siltstone,	nf. lam., p.d.b.
	335.3	dark to light grey siltstone	nf. lam., p.d.b., d.b.,
	411.5	dark to greenish-grey siltstone	nf. lam., p.d.b., d.b., v.b.
Bessie Ck. Sst.	466.3	dark to greenish-grey siltstone, some fine-grained sandstone	nf. lam., p.d.b.
Corcoran Fm.	874.8	grey siltstone, fine sandstone	nf. lam., d.b.
	920.5	grey siltstone, fine sandstone	nf. lam., p.d.b.
	974.8 to	dolerite	
	1148.2	sill	
	1231.0	grey to light greenish grey siltstone	nf. lam., p.d.b.
Hodgson Sst. Mbr.	1304.5	grey siltstone	v.b., d.b.
Mainoru Fm.	2106.2	fine glauconitic sandstone, grey siltstone	nf. lam., v.b., d.b.
	2170.2	fine glauconitic sandstone, grey siltstone	nf. lam., p.d.b., d.b., v.b.
B 8			
McMinn Fm.	17.4	dark grey mudstone	lam., nf. lam., thuch.
	33.2	grey mudstone	nf. lam., p.d.b., thuch.
	59.4	grey mudstone with central 1cm. bed of fine sandstone	nf. lam.
Urapunga 1			
Mainoru Fm.	102.9	very fine grained glauconitic quartz arenite with light grey laminae of siltstone	nf. lam.
	120.9	very fine grained quartz arenite, with light grey laminae of siltstone, laminae distorted and , in places, brecciated	nf. lam.

ABBREVIATIONS

lam. = fluorescent lamalginite; nf. lam. = nonfluorescent lamalginite;
p.d.b. = patchy dispersed bitumen; d.b. = disseminated bitumen;
v.b. = vein bitumen; c.b. = cauliflower bitumen; m.b. = matrix bitumen;
b.m. = bitumen microspheres; oncalg = oncalginite;
thuch. = thucholite

APPENDIX D. Rock and organic matter types, Roper Group, DDH's Broadmere 1, B8, Urapunga 1.

DDH/Fm.	Depth(m)	Lithology	Organic matter types	
Urapunga 3				
Velkerri Fm.	13.3	finely laminated dark grey to light grey siltstone	lam, nf.lam	
	30.3	light-grey siltstone with black laminae; some sub - euhedral pyrite up to 1mm.	lam., nf. lam.	
	54.4	dark grey siltstone, with cross-cutting carbonate-bitumen vein	v.b., nf. lam.	
	75.2	dark grey siltstone	p.d.b., d.b.	
	98.3	dark grey siltstone	v.b., m.b.	
	120.0	dark-grey siltstone with some off-white laminae, phosphatic	nf. lam., p.d.b., d.b.,b.m.,c.b.	
	137.4	dark-grey siltstone with lighter grey laminae	c.b., v.b.	
	150.1	light-grey, easily fractured, siltstone with random black flecks of organic matter ≤ 1mm long, and numerous thin bitumen veins	nf. lam., v.b.	
	172.6	light grey, easily fractured, siltstone with randomly orientated dispersed flecks of organic matter, ≤1mm long	nf. lam.	
	210.7	light grey siltstone with poorly orientated strands of organic matter ≤10mm long	nf. lam., thuch.	
Urapunga 4				
Sherwin Creek Ironstone Member, McMinn Fm.	32.3	fine to medium quartz arenite containing oncolites ≤3mm; patches of reddish clay (?containing hydrated iron oxides) interstitial to quartz grains.	oncolam, v.b., m.b.	
Velkerri Fm.	74.4	dark grey silty claystone, containing some pyrite framboids ≤1mm diam.	lam., nf. lam., thuch.	
	157.3	dark grey mudstone, phosphatic	lam., nf. lam., m.b., b.m., thuch.	
	209.5	dark grey mudstone, phosphatic, grading into fine arenite, containing diagenetic rounded grey to green ?glauconite ≤1mm	lam., nf. lam., m.b., b.m.	
	320.0	dark grey mudstone	nf. lam., p.d.b., d.b., thuch.	
	327.5	dark grey mudstone	nf lam., d.b., p.d.b., thuch.	
	342.7	dark grey mudstone to very fine grained sandstone, containing oil-stained vugs ≤0.5mm long	nf. lam., d.b., p.d.b.	
	348.2	dark grey mudstone to very fine grained sandstone	nf. lam., p.d.b., thuch.	
	354.7	dark grey mudstone	nf. lam., p.d.b., thuch.	
	Corcoran Fm.	433.4	dark grey, faintly laminated, claystone	nf. lam., p.d.b., d.b.
		463.8	dark grey, faintly laminated, claystone, containing black flecks ≤2mm.	nf. lam., p.d.b., d.b.

APPENDIX D ctd. Rock and organic matter types, Roper Group, DDH's Urapunga 3 and 4.

DDH/Fm.	Depth(m)	Lithology	Organic matter types
Urapunga 5			
Jalboi Member	117.4	dark grey siltstone to off-white fine glauconitic sandstone	nf. lam.
	140.0	dark grey siltstone to off-white fine sandstone	nf. lam.
	198.1 to 271.4	dolerite sill	
Arnold Member	323.5	dark grey siltstone to off-white fine sandstone, sandstone dyke	nf. lam.
Mainoru Fm.	590.1	dark grey mudstone to grey siltstone	d.b., thuch.
Urapunga 6			
Mainoru Fm.	57.7	grey siltstone grading into very fine glauconitic sandstone	nf. lam., thuch.
	222.2	grey siltstone grading into very fine sandstone	nf. lam., d.b.
	301.9	grey siltstone and very fine sandstone laminae	nf. lam., d.b., m.b.
X 28			
McMinn Fm.	16.9	grey mudstone	lam., thuch.
	32.0	grey mudstone	lam., thuch.
	61.0	grey mudstone	lam., thuch.
	74.1	grey mudstone to very fine patchy reddish sandstone; sst. dykes.	lam., nf. lam., thuch
	82.9	grey very fine sandstone to pinkish fine sandstone	lam., nf. lam., thuch.

APPENDIX D ctd. Rock and organic matter types, Roper Group, DDH's Urapunga 5 and 6, X28.

DDH/Fm.	Depth(m)	Lithology	Organic matter types
82 / 1			
Cobanbarini Fm.			
"Cat Ck. Member"	193.3	grey mudstone to very fine off-white sandstone	lam., nf. lam., thuch.
"Lansen Ck. Shale"	380.6	grey calcareous mudstone, dissem. quartz-pyrite pseud. after gypsum.	lam., nf. lam., p.d.b., thuch.
	427.8	dark grey mudstone, cross-cutting vein pyrite	nf. lam., thuch.
	560.7	grey mudstone to very fine off-white sandstone	nf. lam., thuch.
82 / 2			
Mainoru Fm.	66.8	grey mudstone grading into very fine glauconitic sandstone	nf. lam.
"Mantungula Fm."	432.9	grey mudstone grading into very fine sandstone	nf. lam.
82 / 3			
Jalboi Member	145.3	grey siltstone to off-white very fine sandstone	nf. lam.
Crawford Fm.	400.7	grey mudstone to off-white glauconitic very fine sandstone	nf. lam., thuch.
Mainoru Fm.	478.5	dark grey mudstone	nf. lam., thuch.
	504.9	grey siltstone to off-white very fine sandstone	nf. lam., thuch.
82 / 8			
Cobanbarini Fm.			
"Lansen Creek	67.4	grey, black flecked, easily fractured, mudstone.	lam., nf. lam.
Shale Member"	100.5	grey siltstone to off-white very fine sandstone.	lam., nf. lam.

APPENDIX D ctd. Rock and organic matter types, Roper Group, DDH's 82/1,3 and 8..

DDH/Fm.	Depth(m)	Area analysed	Elements (In order of abundance)
GR3 Barney Ck. Fm.	30.1	large lamalginite mat large grain in mat (1) large grain in mat (2) diffuse mineral in mat	Si,Ca,K,Fe,Al,Mg,S Si Ca Ca,Al
GR5 Barney Ck. Fm.	72.5	general large mat	Si,Ca,K,S,Al,Fe,Mg Si,Ca,K,S,Al,Fe,Mg
GR7 Barney Ck. Fm.	180.0 B	scour area, general phosphate band organic filament within phosphate band tear-drop nodule lamalginite near nodule pyritic layer above	Si,K,Ca,S,Al,Fe,Mg,P,Ti Ca, P Si,Ca,P Ca,P Si,K,Ca,Al,S,Fe Si,S,Fe,Al,K,Ca
GR9 Barney CK. Fm.	79.1	"waxy" lutite band (1) "waxy" lutite band (2) "non-waxy" lutite band (1) "non-waxy" lutite band (2)	Ca,Si,Mg,K,Al,Fe Ca,Si,S,Fe Si,Ca,K,Al,Mg,Fe,S,Ti Si,Ca,K,Al,Fe=S,Mg,Ti
GR10 Barney Ck. Fm.	23.2	general (1) general (2) large mat(1) large mat(2)	Si,Ca,K,Al,Mg,S,Fe, trace Ti, Si,Ca,K,Al,Mg,Fe,S, trace Ti, Si,Ca,K,Al,Mg,S,Fe Si,S,Ca,K, Fe, Al
	37.4	A general area containing Ti nodules(1) general area containing Ti nodules(2) general area containing Ti nodules(3) Ti-nodule with branching pyritic filament filament itself organic nodule organic nodule lobate-shaped organic nodule general area adjacent to above white mineral in above black mineral in above small organic nodule lobate organic nodule thucholite, whole grain thucholite, central area light grain in central area general area adjacent to thuch. nearby strand of lamalginite (1) nearby strand of lamalginite (2)	Si,K,Al,Ca,Fe,Mg,S,Ti K=Si,Al,Ti,Fe,Mg,S Si,Al,K,S,Fe,Ti Ti,S,Si,Fe,K,Ca S,Fe,Ti Ti,S=Si Ti,S,Si Ti,S,Si Si,Ca,K,Al,Mg,Fe,Ti Si>>Ca, K, Al Si,K,Ca=Al Ti=S,Si Si,S=Ti S>>Si,Fe, Al,Th Si,S,Th Th,Si,S Ca,Si,Mg,K,Al,Fe Si,Mg,K,Ca Si,Ca,Mg,K,Fe,Al
	37.4 B	general	Si,Ca,K,Al,Mg,S,Ti,Fe

**APPENDIX E. Scanning Electron Microscope X-Ray Probe Data,
McArthur Group, DDH'S GR3,7 and 9.**

DDH/Fm.	Depth(m)	Area analysed	Elements (in order of abundance)
GR10 ctd.			
Barney Ck. Fm.	51.4	strew mount	
		general	Si,S,Ca,Fe,Mg,K
		organic matter (1)	Si,Ca,S,Fe
		organic matter (2)	Si,Ca,Ti
	92.6	general	Si,Al,K,Ca, S,Fe,Mg,trace Ti
		spot grain analysis (1)	Si
		spot grain analysis (2)	Si
		spot grain analysis (3)	Si,AL,K=Ca,Ti
		mat	Si,K,Al,Mg,Ti, trace S
	238.8	thucholite grain 1	
		whole area	S>>Si,Th,Fe
		small rectangular grain near center	S,Th,Si
		small square grain near center	S>>Th>>Si
		rect. grain near center	S>>Si,Al,K,Fe
		thucholite grain 2	
		irregular small grain near center	S,Th,Si
		ditto	S,Si=Th,Fe
		ditto	S>>Si,Th,Ca,Fe,P
		ditto	S,Si,Th,Fe
	297.2	thucholite 1, general	S,Si,Th
		small central triangular grain ,	
		amongst several in the area	S,Th,Si
		small peripheral patch	S>>Si,Ca
		thucholite 2	
		whole grain	S,Si,Th,P,Fe
		one white grain amongst several near	
		central area	Si,Th
		white ring near edge	Si,Th
		thucholite 3	
		spot (probe) just outside grain	Si,Al,Ca,Mg
		probe on edge of thuch. 2	Si,Ca,Mg,Fe,S,K
		probe in central area of thuch. 2	S>>P,Al,Mg,Fe
	602.5	thucholite grain	
		rectangular white central grain	S,Th,Si
		mineral matrix (1)	Si,Al,K,Fe,Ti,S, Mg
		mineral matrix (2)	Si,Al,Ca
N 27 / 63			
Barney Ck. Fm.	105.5	general	Si,S,Fe,Ca=K,Al,Mg,Zn,Ti
		discrete grain of ?bitumen	Si,S,Fe,Ca=K,Al,Mg,Zn,Ti
		composite grain of ?bitumen	Zn,Ti,Si,S,K,Ca,Al,Fe
	172.8	cross-cutting bitumen vein	
		area	Ca,Si,K,Fe,Mg,Al,Cu

DDH/Fm.	Depth(m)	Area analysed	Elements (In order of abundance)
Broadmere 1			
Velkerri Fm.	109.7	general microsphere, 3 μ diameter	Si,Al,K,Ca,S,Fe,P Ca, P
Urapunga 3			
Velkerri Fm.	49.8	general area containing microspheres	Si,Al,K,Ca=Fe,S,Mg,Ti Si,Ca,Al,Fe=S,P
		microsphere 1	Ca, P
		microsphere 2	Ca, P
	98.3	general bitumen vein	Si,Ca,Al,Fe,K,S,P trace S
Urapunga 4			
Velkerrie Fm.	32.3	oolitic ironstone central grain of oolite	Si
		oolite rings	Fe,Si=Al,Ca,Mg,S
	157.3	general	Si,Al,K,Fe,Ca, Ti
		microsphere, 6 μ diameter	Ca,P
	342.7	general	Si,Al,K,Mg,Ti

APPENDIX E ctd. Scanning Electron Microscope X-Ray Probe Data, Roper Group, Broadmere 1, Urapunga 3 and 4.

DDH/Fm. GR 1	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
Barney Ck.	26.5	lam.	0.146	0.132	0.160	0.11	0.18	12	0.130	0.119	0.141	0.10	0.16	12
	92.2	lam.	0.190	0.179	0.201	0.16	0.23	16	0.160	0.151	0.169	0.14	0.18	16
	279.5	nf. lam.	0.564	0.537	0.590	0.50	0.62	11	0.485	0.463	0.507	0.43	0.53	11
	320.2	nf. lam., d.b.	0.641	0.603	0.680	0.50	0.75	15	0.505	0.461	0.549	0.37	0.69	15
GR 2														
Barney Ck.	62.9	lam.	0.146	0.136	0.155	0.12	0.17	11	0.123	0.117	0.129	0.11	0.14	11
	180.5	lam.	0.184	0.171	0.197	0.14	0.24	17	0.165	0.152	0.178	0.12	0.22	17
	238.2	nf. lam., p.d.b.	0.356	0.311	0.400	0.29	0.47	11	0.272	0.237	0.307	0.21	0.37	11
	238.2	lam.	0.236	0.207	0.265	0.20	0.26	5	0.194	0.162	0.226	0.17	0.23	5
GR 3														
Barney Ck.	30.1	lam.	0.124	0.116	0.131	0.10	0.14	11	0.113	0.106	0.120	0.09	0.12	11
	162.8	lam.	0.225	0.213	0.237	0.19	0.27	14	0.192	0.182	0.202	0.17	0.24	14
	302.6	d.b., m.b.	0.440	0.424	0.456	0.38	0.49	15	0.387	0.364	0.410	0.33	0.45	15
GR 4														
Barney Ck.	107.7	lam.	0.342	0.315	0.369	0.26	0.49	21	0.267	0.243	0.291	0.19	0.41	21
	129.5	nf. lam., p.d.b.	0.386	0.363	0.410	0.33	0.45	14	0.299	0.274	0.323	0.24	0.37	14
	151.4	p.d.b.	0.682	0.639	0.724	0.55	0.76	13	0.480	0.425	0.536	0.36	0.58	13
	162.6	p.d.b., v.b.	0.832	0.800	0.864	0.75	0.94	13	0.658	0.623	0.694	0.59	0.77	12

ABBREVIATIONS:

lam. = fluorescent lamalginite

nf. lam. = nonfluorescent lamalginite

p.d.b. = patchy dispersed bitumen

d.b. = disseminated bitumen

m.b. = matrix bitumen

v.b. = vein bitumen

maxRo = mean maximum reflectance

minRo = mean minimum reflectance

95%max/min = maximum/minimum value of the mean at the 95% confidence level.

X-max/min = range

No. = number of measurements taken

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.	
GR 5	Barney Ck.	72.5	lam.	0.120	0.108	0.132	0.09	0.15	12	0.105	0.094	0.116	0.08	0.13	12
		150.0	lam.	0.171	0.161	0.182	0.14	0.20	14	0.153	0.143	0.163	0.13	0.18	14
		306.3	lam.	0.341	0.298	0.386	0.26	0.40	7	0.252	0.194	0.309	0.17	0.34	6
		306.3	p.d.b.,d.b.,nf. lam.	0.561	0.504	0.618	0.45	0.71	12	0.430	0.390	0.470	0.35	0.52	12
		426.0	p.d.b.,d.b., nf. lam.	0.673	0.645	0.702	0.56	0.75	15	0.516	0.492	0.540	0.44	0.59	15
		494.8	lam.	0.414	0.382	0.447	0.29	0.55	19	0.311	0.281	0.340	0.20	0.45	19
		494.8	nf. lam., p.d.b., d.b.	0.786	0.768	0.804	0.71	0.87	21	0.658	0.638	0.678	0.58	0.77	21
GR7	Barney Ck.	38.7	lam.	0.113	0.105	0.120	0.09	0.14	15	0.097	0.091	0.103	0.08	0.12	15
		50.3	lam.	0.131	0.122	0.139	0.10	0.16	15	0.116	0.110	0.122	0.10	0.13	14
		238.8	lam.	0.170	0.162	0.178	0.15	0.20	15	0.149	0.143	0.155	0.13	0.17	15
		426.7	lam.	0.311	0.275	0.348	0.20	0.43	14	0.252	0.222	0.282	0.17	0.33	14
		601.5	lam.	0.310	0.249	0.371	0.25	0.41	7	0.260	0.218	0.302	0.22	0.33	7
		601.5	p.d.b., nf. lam.	0.693	0.623	0.762	0.37	0.88	15	0.539	0.482	0.597	0.29	0.71	15
		794.6	p.d.b.	1.082	1.038	1.127	0.87	1.21	17	0.867	0.835	0.898	0.74	0.97	17
GR 8	Barney Ck.	854.0	p.d.b.	1.015	0.969	1.061	0.88	1.16	16	0.796	0.771	0.821	0.70	0.87	16
		49.2	lam.	0.161	0.150	0.172	0.13	0.19	13	0.135	0.127	0.144	0.12	0.16	13
		349.3	p.d.b., d.b.	0.779	0.710	0.848	0.62	0.98	12	0.549	0.474	0.624	0.41	0.71	11
		451.0	p.d.b.,d.b.	0.912	0.847	0.978	0.74	1.03	9	0.673	0.618	0.729	0.54	0.67	9
		570.8	p.d.b.,d.b.	1.003	0.965	1.042	0.87	1.20	21	0.818	0.781	0.854	0.65	0.99	21

APPENDIX F ctd. Reflectance measurements of lamalginite and/or bitumen, Nathan and McArthur Groups, Glyde River Subbasin, DDHS GR5 to 8.

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
GR9														
Barney Ck. Fm.	79.1	lam.	0.048	0.040	0.055	0.03	0.06	9						
	337.8	lam.	0.270	0.242	0.298	0.20	0.36	14	0.221	0.196	0.247	0.16	0.31	14
	422.2	p.d.b.,nf. lam.	0.440	0.390	0.490	0.32	0.62	16	0.325	0.280	0.370	0.21	0.50	16
	500.1	p.d.b., nf. lam.	0.655	0.625	0.685	0.55	0.76	17	0.511	0.476	0.545	0.39	0.62	17
GR10														
Barney Ck. Fm.	37.4	lam.	0.129	0.118	0.140	0.10	0.20	26	0.115	0.105	0.124	0.08	0.18	26
	88.4	lam.	0.124	0.111	0.137	0.08	0.23	26	0.096	0.085	0.106	0.06	0.17	26
	143.3	lam.	0.135	0.130	0.141	0.11	0.16	26	0.123	0.118	0.127	0.10	0.15	26
	232.8	lam.	0.169	0.158	0.179	0.11	0.21	26	0.143	0.135	0.152	0.10	0.19	24
	297.2	lam.	0.236	0.221	0.250	0.17	0.30	25	0.189	0.174	0.203	0.13	0.27	25
	410.0	lam.	0.271	0.252	0.289	0.18	0.33	17	0.238	0.201	0.275	0.16	0.45	15
	443.0	nf. lam., p.d.b., v.b.	0.515	0.497	0.534	0.37	0.58	25	0.414	0.387	0.440	0.27	0.47	17
	514.2	lam.	0.365	0.347	0.383	0.26	0.44	21	0.298	0.268	0.328	0.20	0.33	10
	575.3	lam.	0.397	0.359	0.435	0.25	0.57	21	0.358	0.310	0.405	0.25	0.50	12
	575.3	nf. lam., p.d.b., d.b.	0.668	0.642	0.694	0.58	0.75	15	0.537	0.476	0.597	0.48	0.62	6
	602.5	p.d.b., nf. lam.	0.718	0.683	0.754	0.54	0.90	23	0.587	0.545	0.628	0.43	0.73	18
	646.9	v.b.	0.868	0.831	0.906	0.68	0.99	25	0.754	0.720	0.789	0.58	0.96	24
	662.1	v.b.	0.896	0.871	0.922	0.75	1.02	25	0.789	0.761	0.817	0.64	0.93	25
GR 11														
Barney Ck.	96.9	lam.	0.249	0.232	0.267	0.19	0.29	12	0.210	0.192	0.228	0.15	0.25	12
	202.8	lam.	0.332	0.314	0.350	0.30	0.37	11	0.272	0.254	0.290	0.24	0.31	11
	202.8	nf. lam., p.d.b.	0.490	0.430	0.469	0.39	0.49	12	0.367	0.344	0.389	0.31	0.37	12
	258.7	p.d.b, nf. lam.	0.702	0.666	0.738	0.59	0.80	13	0.590	0.553	0.627	0.47	0.67	13
	347.3	p.d.b.	0.808	0.778	0.837	0.70	0.95	21	0.685	0.647	0.723	0.57	0.84	21
	415.2	p.d.b.	1.017	0.979	1.055	0.90	1.12	17	0.812	0.764	0.861	0.60	0.98	17
	442.0	p.d.b., nf. lam.	1.054	0.993	1.114	0.87	1.25	17	0.835	0.780	0.890	0.68	1.02	17

APPENDIX F ctd. Reflectance measurements of lamalginite and/or bitumen, Nathan and McArthur Groups, Glyde River Subbasin, DDH'S GR10 and 11.

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
BB2														
Reward Dolomite	72.0	p.d.b., d.b.	1.906	1.732	2.080	1.53	2.20	9	1.232	1.067	1.397	0.91	1.60	9
Barney Ck. Fm.	273.3	p.d.b.	2.292	1.964	2.619	1.95	2.75	6	1.508	1.184	1.833	1.15	1.80	6
	374.0	m.b.	2.766	2.687	2.845	2.30	3.20	25	1.698	1.641	1.755	1.30	1.90	25
BJ1														
Lynott Fm.	10.2	p.d.b.	1.969	1.736	2.202	1.40	3.10	16	1.241	1.060	1.421	0.80	2.10	16
Barney Ck. Fm.	30.6	p.d.b.	2.521	2.366	2.675	1.90	3.10	17	1.632	1.535	1.729	1.30	2.10	17
Teena Dolomite	95.2	p.d.b., v.b.	2.129	1.974	2.283	1.60	2.70	21	1.433	1.328	1.538	1.10	1.90	21
CA1														
Reward Dol.	253.7	p.d.b., d.b.	1.894	1.737	2.052	1.70	2.20	7						
Barney Ck. Fm.	337.6	nf. lam	2.214	1.925	2.504	1.60	2.50	7						
CA3														
Barney Ck. Fm.	481.4	v.b.	3.116	3.012	3.220	2.80	3.45	15						
Leila Yard 1														
Lynott Fm.	21.4	nf. lam., p.d.b.	1.344	1.250	1.437	1.23	1.58	8	1.118	1.055	1.180	1.02	1.22	8
	156.8	p.d.b.	1.458	1.275	1.640	1.35	1.60	4	0.888	0.768	1.001	0.80	0.95	4
	271.4	nf. lam, p.d.b.	2.056	1.903	2.208	1.88	2.38	7	1.311	1.108	1.515	1.03	1.60	7
Barney Ck. Fm.	408.5	p.d.b., d.b.	2.261	2.138	2.385	1.95	2.55	10	1.575	1.463	1.687	1.40	1.85	10
	500.0	d.b.	2.518	2.409	2.627	2.12	2.95	18	1.710	1.596	1.824	1.40	2.10	18
MANT 79-3														
Reward Dolomite	279.8	v.b.	2.596	2.463	2.729	2.25	3.10	12	1.771	1.680	1.862	1.60	2.05	12
Barney Ck. Fm.	349.8	nf. lam.	2.220	2.058	2.382	1.77	2.55	11	1.307	1.221	1.394	1.10	1.50	11

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No. minRo%	95%min	95%max	X-min	X-max	No.
McA 5													
Barney Ck. Fm.	74.0	p.d.b.,d.b.,nf. lam.	1.345	1.237	1.453	1.02	1.95	23	1.010	1.105	0.75	1.65	23
	138.2	p.d.b.,d.b.,nf. lam.	1.307	1.219	1.396	0.80	1.70	25					
Teena Dolomite	441.4	v.b.	1.827	1.777	1.877	1.58	2.05	25	1.376	1.437	1.03	1.59	25
McA 10													
Barney Ck. Fm.	27.8	nf. lam., p.d.b., d.b.	1.968	1.817	2.119	1.60	2.35	12	1.499	1.405	1.20	1.75	12
Teena Dolomite	139.3	v.b., d.b.	2.812	1.880	3.744	1.91	3.60	5					
Emmerugga Dol.	160.7	v.b.	3.045	3.018	3.072	2.95	3.21	25	2.864	2.836	2.75	3.02	25
	243.1	v.b.	2.428	2.329	2.527	1.95	2.95	25	1.788	1.740	1.50	2.05	25
MY5													
Reward Dol.	67.2	v.b.	1.121	1.091	1.152	1.01	1.29	21	0.904	0.877	0.82	1.10	21
Barney Ck. Fm.	288.0	p.d.b.	1.240	1.164	1.316	1.12	1.35	8	0.909	0.844	0.81	1.07	8
	330.7	p.d.b., nf. lam.	1.394	1.343	1.446	1.28	1.48	9	1.114	1.036	1.00	1.30	9
M17/08													
Barney Ck. Fm.	112.0	p.d.b., d.b., m.b., v.b.	1.510	1.420	1.610	1.28	2.05	18					
	339.5	p.d.b., d.b.	2.400	2.310	2.490	2.25	2.55	9					
	351.4	nf. lam., v.b., d.b.	2.030	1.970	2.090	1.68	2.22	22					
N27/63													
Barney Ck. Fm.	31.7	nf. lam., v.b., d.b.	2.060	2.000	2.130	1.90	2.22	11					
	105.5	p.d.b.,d.b.,v.b.	2.170	2.090	2.250	1.82	2.43	18					
	172.8	v.b.	2.190	2.140	2.230	2.00	2.28	13					
	313.0	nf. lam., p.d.b., d.b.	3.150	2.720	3.580	2.10	4.10	10					
	335.0	d.b.	5.390	5.100	5.680	4.80	6.10	11					
	380.9	d.b.,p.d.b.	2.110	2.000	2.220	1.65	2.67	25					
	388.9	v.b.	2.080	1.840	2.310	1.82	2.25	5					

APPENDIX F ctd. Reflectance measurements of lamalinite and/or bitumen, Nathan and McArthur Groups, central and northern Batten Trough, DDH's McA5 - N27/63.

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
WM6														
Barney Ck. Fm.	200.8	d.b.	1.473	1.346	1.599	1.20	1.77	12	0.932	0.796	1.068	0.70	1.35	12
	423.6	nf. lam., d.b.	1.871	1.736	2.007	1.47	2.22	15	1.346	1.180	1.512	0.88	1.80	15
	519.3	d.b.	2.107	1.925	2.290	1.75	2.65	11	1.402	1.299	1.505	1.20	1.65	11
8 2 / 4														
Balbarini Dol.	84.2	v.b., p.d.b.	4.190	4.050	4.330	3.85	4.45	10	2.575	2.450	2.700	2.40	2.90	10
unspec. McA. Gp.	468.7	v.b., p.d.b.	5.444	5.282	5.607	5.10	5.80	9	3.128	2.721	3.534	2.10	3.90	9
8 2 / 5														
Lynott Fm.	54.7	p.d.b.	1.551	1.431	1.672	1.30	1.68	7	1.064	0.885	1.244	0.80	1.38	7
	191.7	p.d.b.	1.652	1.521	1.783	1.44	1.80	6	1.197	1.034	1.359	0.98	1.41	6
	453.6	p.d.b.	2.763	2.544	2.981	2.50	3.20	8	1.875	1.711	2.039	1.65	2.20	8
8 2 / 6														
Yalco Fm.	125.7	lam.	0.136	0.129	0.144	0.12	0.15	11	0.121	0.112	0.130	0.10	0.14	11
Lynott Fm.	290.3	lam.	0.266	0.252	0.280	0.24	0.30	10	0.228	0.216	0.240	0.21	0.25	10
8 2 / 7														
Balbarini Dolomite	55.5	v.b.	0.789	0.765	0.814	0.73	0.87	14	0.699	0.669	0.730	0.61	0.82	14
Yalco Fm.	186.3	lam.	0.389	0.361	0.416	0.32	0.47	13	0.308	0.282	0.334	0.25	0.39	14
	186.3	nf. lam.	0.781	0.708	0.854	0.56	0.89	11	0.620	0.549	0.691	0.40	0.73	11
Lynott Fm.	327.5	v.b.	1.512	1.464	1.560	1.33	1.67	17	0.660	0.615	0.705	0.43	0.79	17

depth(m)	diam.(mμ)	maxRo%	95%min.	95%max.	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
17.4	8 - 177	0.524	0.496	0.552	0.41	0.67	24	0.435	0.408	0.463	0.31	0.58	24
11.2	5 - 170	0.654	0.574	0.734	0.33	1.35	34	0.539	0.475	0.603	0.29	0.95	32
152.1	10 - 130	0.531	0.492	0.570	0.25	0.81	54	0.459	0.424	0.495	0.21	0.73	54
114.2	40 - 190	0.648	0.606	0.690	0.35	0.80	30	0.550	0.511	0.590	0.42	0.76	28
38.5	13 - 100	0.779	0.681	0.877	0.49	1.27	19	0.670	0.588	0.751	0.38	1.02	19
37.4	<50	0.517	0.489	0.546	0.41	0.67	22	0.430	0.400	0.459	0.31	0.58	22
81.2	<50	0.467	0.426	0.508	0.33	0.62	13	0.398	0.349	0.447	0.29	0.55	12
252.1	<50	0.449	0.400	0.499	0.25	0.81	30	0.390	0.345	0.435	0.21	0.70	30
514.2	<50	0.638	0.547	0.729	0.48	0.78	10	0.550	0.511	0.590	0.42	0.76	10
638.5	<50	0.703	0.630	0.777	0.49	0.91	15	0.616	0.539	0.693	0.38	0.80	15

ABBREVIATIONS:

- diam.(mμ) = diameter of the thucholite grain in microns,
- maxRo = mean maximum reflectance,
- minRo = mean minimum reflectance,
- 95%max/min = maximum/minimum value of the mean at the 95% confidence level,
- X-max/min = range,
- No. = number of measurements taken.

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min	95%max	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
BROADMERE 1														
Cobanbirini Fm.	27.4	lam.	0.272	0.197	0.346	0.17	0.37	6	0.468	0.447	0.490	0.35	0.57	25
	27.4	nf. lam.	0.598	0.570	0.626	0.45	0.72	25	0.589	0.543	0.635	0.43	0.84	22
	109.7	nf. lam.	0.731	0.686	0.776	0.49	1.00	25	0.589	0.543	0.635	0.43	0.84	22
	155.4	nf. lam.	0.892	0.858	0.926	0.72	1.01	25	0.702	0.678	0.726	0.61	0.85	25
	335.3	nf. lam., p.d.b.	1.318	1.255	1.381	0.98	1.55	25	1.048	0.986	1.111	0.62	1.27	25
	411.5	nf. lam., p.d.b., d.b.	1.737	1.654	1.820	1.47	2.10	25	1.284	1.222	1.345	1.04	1.60	25
	466.3	nf. lam, p.d.b.	1.464	1.412	1.516	1.25	1.68	25	1.082	1.031	1.133	0.72	1.23	25
	874.8	nf. lam.	3.033	2.522	3.545	2.35	4.10	9	1.963	1.641	2.284	1.60	2.75	8
	920.5	nf. lam., p.d.b.	4.727	4.288	5.167	4.00	5.90	11	3.090	2.504	3.676	2.10	4.30	10
	1231.0	nf. lam., p.d.b.	5.238	4.552	5.923	4.40	6.90	8	2.400	2.216	2.584	2.30	2.50	4
Hodgson Sst. Mbr.	1304.5	v.b.	5.338	4.188	6.487	3.50	7.00	8	4.163	2.879	5.446	2.30	6.00	8
Mainoru Fm.	2106.2	nf. lam., v.b., d.b.	3.863	3.653	4.072	3.50	4.30	8	2.433	2.072	2.795	2.10	3.00	6
	2170.2	nf. lam., p.d.b.,d.b., v.b.	3.540	3.176	3.904	3.00	4.70	10	2.413	1.958	2.867	1.90	3.60	8
B8														
McMinn Fm.	17.4	lam.	0.237	0.215	0.258	0.19	0.29	12	0.197	0.180	0.214	0.16	0.24	12
	17.4	nf. lam.	0.433	0.397	0.469	0.35	0.51	11	0.344	0.310	0.378	0.26	0.41	11
	33.2	nf. lam.	1.096	1.061	1.122	1.01	1.20	11	0.896	0.877	0.914	0.85	0.95	11
	59.4	nf. lam.	3.492	3.281	3.702	3.00	4.30	12	1.746	1.384	2.107	0.90	2.60	12

ABBREVIATIONS:

lam. = fluorescent lamalginite

nf. lam. = nonfluorescent lamalginite

p.d.b. = patchy dispersed bitumen

d.b. = disseminated bitumen

m.b. = matrix bitumen

v.b. = vein bitumen

oncalg. = oncalginite

c.b. = cauliflower bitumen

maxRo = mean maximum reflectance

minRo = mean minimum reflectance

95%max/min = maximum/minimum value of the mean at the 95% confidence level.

X-max/min = range

No. = number of measurements taken

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min	95%max	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
URAPUNGA 1														
Mainoru Fm.	102.9	nf. lam.	2.696	2.568	2.824	2.40	3.10	12	1.646	1.534	1.758	1.40	1.95	12
	120.9	nf. lam.	2.672	2.507	2.838	2.50	3.20	9	1.461	1.355	1.568	1.25	1.65	9
URAPUNGA 3														
Velkerri Fm.	13.3	lam.	0.231	0.205	0.257	0.10	0.37	22						
	13.3	nf. lam.	0.419	0.387	0.451	0.27	0.59	26						
	30.3	lam.	0.299	0.276	0.323	0.22	0.33	10	0.256	0.237	0.275	0.20	0.28	10
	30.3	nf. lam.	0.662	0.622	0.702	0.56	0.82	15	0.543	0.493	0.593	0.44	0.72	15
	54.4	v.b.	0.790	0.759	0.821	0.53	0.90	25	0.673	0.648	0.697	0.46	0.75	25
	75.2	p.d.b., d.b.	1.021	0.998	1.045	0.91	1.12	25	0.884	0.857	0.912	0.75	1.00	25
	98.3	v.b.	1.691	1.626	1.756	1.37	1.90	23	0.527	0.484	0.569	0.39	0.69	23
	120.0	d.b., c.b.	1.929	1.853	2.005	1.53	2.40	31	1.103	1.030	1.176	0.83	1.75	30
	172.6	nf. lam.	2.341	2.276	2.406	2.17	2.52	16	1.795	1.700	1.891	1.50	2.25	16
	210.7	nf. lam.	3.418	3.296	3.540	2.86	3.90	25	2.257	2.164	2.350	1.65	2.60	25
URAPUNGA 4														
McMinn Fm.	32.3	oncalg., m.b., v.b.	1.543	1.418	1.668	1.27	1.95	15	1.207	1.061	1.354	1.02	1.70	11
Velkerri Fm.	74.4	nf. lam.	0.612	0.573	0.651	0.42	0.78	25	0.476	0.434	0.518	0.29	0.69	25
	157.3	lam.	0.279	0.258	0.301	0.22	0.35	14	0.247	0.230	0.264	0.19	0.30	14
	157.3	nf. lam.	0.501	0.475	0.528	0.38	0.68	30	0.441	0.416	0.466	0.31	0.59	30
	209.5	lam.	0.288	0.267	0.309	0.22	0.35	18	0.256	0.237	0.274	0.19	0.31	18
	209.5	nf. lam.	0.594	0.527	0.661	0.37	0.83	22	0.551	0.477	0.626	0.27	0.81	22
	320.0	nf. lam., d.b.	1.082	0.976	1.188	0.78	1.53	25	0.867	0.785	0.949	0.64	1.21	25
	327.5	nf. lam.	0.920	0.849	0.992	0.64	1.22	24	0.806	0.722	0.890	0.43	1.14	24
	342.7	nf. lam.	0.981	0.920	1.041	0.62	1.27	32	0.779	0.745	0.853	0.46	0.99	29
	348.2	nf. lam.	1.047	1.005	1.089	0.79	1.21	25	0.864	0.824	0.904	0.61	1.03	25
	354.7	nf. lam.	1.090	1.045	1.136	0.88	1.28	25	0.946	0.899	0.994	0.75	1.16	24
	433.4	nf. lam., d.b.	1.350	1.296	1.405	1.08	1.62	25	1.134	1.093	1.176	0.83	1.23	25
Corcoran Fm.	463.8	nf. lam., p.d.b., d.b.	1.419	1.362	1.476	1.18	1.71	25	1.126	1.030	1.222	0.28	1.47	25

APPENDIX G ctd. Reflectance measurements of lamalginite and/or bitumen, Roper Group, DDH'S Urapunga 1 to 4.

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min	95%max	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
URAPUNGA 5														
Jalboi Member	117.4	nf. lam.	3.291	3.096	3.486	2.80	3.80	11	1.805	1.592	2.017	1.20	2.20	11
	140.0	nf. lam.	4.250	3.905	4.595	3.10	5.30	15	2.357	2.139	2.574	1.70	3.10	15
Arnold Memb.	323.5	nf. lam.	4.267	4.115	4.418	3.70	4.90	21	2.486	2.324	2.648	2.10	3.30	21
Mainoru Fm.	590.1	d.b.	2.314	2.146	2.464	2.00	3.00	18	1.423	1.307	1.539	1.00	1.90	15
URAPUNGA 6														
Mainoru Fm.	57.7	nf. lam.	1.479	1.397	1.561	1.30	1.67	11	1.116	1.065	1.168	1.00	1.22	11
	222.2	nf. lam.	2.229	2.177	2.284	2.11	2.32	8	1.358	1.173	1.542	1.05	1.60	8
	301.9	nf. lam, d.b.	2.318	2.198	2.437	1.90	2.75	16	1.483	1.398	1.567	1.25	1.75	16
X28														
McMinn Fm.	16.9	lam.	0.199	0.184	0.214	0.15	0.24	17	0.159	0.151	0.167	0.13	0.18	17
	32.0	lam.	0.161	0.148	0.173	0.12	0.21	18	0.135	0.125	0.145	0.11	0.18	18
	61.0	lam.	0.204	0.183	0.226	0.16	0.25	9	0.171	0.153	0.189	0.14	0.21	9
	74.1	lam.	0.439	0.401	0.478	0.34	0.57	16	0.321	0.278	0.364	0.21	0.49	16
	82.9	lam.	0.396	0.365	0.426	0.33	0.45	9	0.277	0.248	0.306	0.21	0.34	9

DDH/Fm.	Depth(m)	Maceral	maxRo%	95%min	95%max	X-min	X-max	No.	minRo%	95%min	95%max	X-min	X-max	No.
3 2 / 1														
Cobanbirini Fm.	193.3	nf. lam.	0.722	0.605	0.837	0.48	0.98	10	0.513	0.422	0.604	0.38	0.72	10
'Cat Ck. Member"	193.3	lam.	0.386	0.372	0.400	0.37	0.41	7	0.284	0.242	0.326	0.21	0.33	7
'Lansen Ck. Shale"	380.6	lam.	0.470	0.432	0.508	0.43	0.52	6	0.367	0.334	0.399	0.32	0.40	6
	380.6	nf. lam., p.d.b.	0.974	0.892	1.056	0.73	1.17	12	0.755	0.685	0.825	0.50	0.90	12
	427.6	nf. lam.	0.997	0.907	1.088	0.72	1.19	11	0.768	0.684	0.852	0.49	0.97	11
	560.7	nf. lam., d.b.	1.318	1.171	1.464	1.13	1.63	8						
3 2 / 2														
Mainoru Fm.	66.8	nf. lam.	2.213	2.109	2.316	2.08	2.40	8	1.625	1.562	1.688	1.53	1.72	8
'Mantungula Fm."	432.9	nf. lam.	2.777	2.687	2.868	2.60	3.05	11	1.973	1.896	2.050	1.80	2.15	11
8 2 / 3														
Jalboi Member	145.3	nf. lam., d.b.	2.388	2.275	2.501	2.05	2.75	14	1.671	1.579	1.764	1.38	1.95	14
Crawford Fm.	400.7	nf. lam.	1.801	1.609	1.992	1.30	2.27	12	1.348	1.169	1.528	0.93	1.76	12
Mainoru Fm.	478.5	nf. lam.	2.096	2.020	2.171	1.90	2.33	11	1.575	1.492	1.657	1.33	1.73	11
	504.9	nf. lam.	2.096	1.952	2.240	1.53	2.4	12	1.397	1.230	1.563	0.82	1.62	12
8 2 / 8														
Cobanbirini Fm.	67.4	lam.	0.324	0.303	0.344	0.28	0.37	11	0.248	0.232	0.265	0.21	0.29	11
"Lansen Ck. Shale"	67.4	nf. lam.	0.774	0.659	0.889	0.55	0.98	8	0.573	0.457	0.688	0.34	0.78	8
	100.5	lam.	0.527	0.451	0.602	0.50	0.56	3	0.323	0.261	0.385	0.30	0.35	3
	100.5	nf. lam.	0.828	0.741	0.915	0.64	1.13	14	0.548	0.476	0.620	0.40	0.76	14

APPENDIX G. Reflectance measurements of lamalginite and/or bitumen, Roper Group, DDH'S 82/1 to 82/8.

APPENDIX H. Mean maximum reflectance (maxRo%) histograms for selected samples containing both fluorescent and nonfluorescent lamalginite; McArthur Group, Glyde River Subbasin.

APPENDIX H ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing both fluorescent and nonfluorescent lamalginite; McArthur Group, Glyde River Subbasin.

APPENDIX H ctd. Mean maximum reflectance (maxRo%)

histograms for selected samples containing both fluorescent and nonfluorescent lamalginite, McArthur Group from the central and northern Batten Trough; and Roper Group

APPENDIX H ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing both fluorescent and nonfluorescent lamalginite; Roper Group.

APPENDIX H ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing both fluorescent and nonfluorescent lamalginite; Roper Group.

APPENDIX I. Mean maximum reflectance (maxRo%) histograms for selected samples containing nonfluorescent lamalginite and/or bitumen; McArthur Group, Glyde River Subbasin.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginite and/or bitumen; McArthur Group, Glyde River Subbasin.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginite and/or bitumen; McArthur Group, Glyde River Subbasin.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginite and/or bitumen; McArthur Group, central and northern Batten Trough.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginite and/or bitumen; McArthur Group, central and northern Batten Trough.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginite and/or bitumen; Roper Group.

APPENDIX I ctd. Mean maximum reflectance (maxRo%) histograms for selected samples containing lamalginites and/or bitumen; Roper Group.

$$y = 0.6664 - 0.0056x + 6.362e-4x^2 - 6.276e-6x^3 + 1.606e-8x^4 \quad R = 0.98$$

$$y = 0.5352 + 0.0105x - 8.753e-5x^2 + 1.749e-7x^3 + 0.000e+0x^4 \quad R = 0.98$$

$$y = 0.7777 - 0.019x + 0.004x^2 - 9.630e-5x^3 + 6.084e-7x^4 \quad R = 0.99$$

APPENDIX J. Random reflectances (Ro%) across a section through a thucholite grain; DDH GR10, Barney Creek Formation, Glyde River Subbasin

$y = 0.7622 + 0.0357x + 0.0045x^2 - 1.240e-4x^3 + 7.745e-7x^4 \quad R = 0.99$

edge A   distance from edge A (microns)   edge B

$y = 0.5562 - 0.0213x + 0.0065x^2 - 1.214e-4x^3 + 5.896e-7x^4 \quad R = 0.99$

edge A   distance from edge A (microns)   edge B

$y = 0.2492 + 0.0634x - 0.0077x^2 + 3.686e-4x^3 - 6.255e-6x^4 \quad R = 0.98$

edge A   distance from edge A (microns)   edge B

APPENDIX J ctd. Random reflectances (Ro%) across a section through a thucholite grain; DDH GR10, Barney Creek Formation, Glyde River Subbasin.

$$y = 0.2338 + 0.0042x + 0.0032x^2 - 3.705e-4x^3 + 8.632e-6x^4 \quad R = 0.99$$

$$y = 0.3495 + 0.0894x - 0.0162x^2 + 0.001x^3 - 2.196e-5x^4 \quad R = 0.87$$

$$y = 0.1854 + 0.0297x - 8.899e-4x^2 + 1.124e-5x^3 - 1.243e-7x^4 \quad R = 0.98$$

APPENDIX J. Random reflectances (Ro%) across a section through a thucholite grain; DDH GR10, Barney Creek Formation, Glyde River Subbasin.

ABBREVIATIONS:

lam = fluorescent lamalginite,
 nf. lam = nonfluorescent lamalginite,
 d.b. = dispersed bitumen,
 m.b. = matrix bitumen,
 p.d.b. = patchy dispersed bitumen,
 v.b. = vein bitumen,

APPENDIX K. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Barney Creek Formation, Glyde River Subbasin. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Barney Creek Formation, Glyde River Subbasin. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Barney Creek Formation, Glyde River Subbasin. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; northern and central Batten Trough. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; northern and central Batten Trough. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; northern and central Batten Trough. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX K ctd. Reflectances (Ro%) of lamalginites and/or bitumen versus depth; northern and central Batten Trough. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

ABBREVIATIONS:

- lam = fluorescent lamalginite,
- nf. lam = nonfluorescent lamalginite,
- oncalg. = oncalginite
- d.b. = dispersed bitumen,
- m.b. = matrix bitumen,
- p.d.b. = patchy dispersed bitumen,
- v.b. = vein bitumen,
- c.b. = cauliflower bitumen

APPENDIX L. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Roper Group. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX L ctd. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Roper Group. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line. Oil bubbled out of a 0.1 m section of core (arrow) in Urupunga 4 (Jackson et al., 1986).

APPENDIX L ctd.. Reflectances (Ro%) of lamalginite and/or bitumen versus depth; Roper Group. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

APPENDIX L ctd. Reflectances (Ro%) of lamalginites and/or bitumen versus depth; Roper Group. Mean reflectance values are represented by the vertical lines, 95% confidence limits of the mean by the black rectangles and the range by the horizontal line.

Glyde River Subbasin, model 1a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck.	20-30	1.95	0.0039	0.01	0.01
	30-40	1.95	0.0078	0.02	0.03
Fm. from 1690 to 1670 Ma.	40-50	1.95	0.0156	0.03	0.06
	50-60	1.95	0.0313	0.06	0.12
	60-70	1.95	0.0625	0.12	0.24
	70-80	1.95	0.125	0.24	0.48
	80-90	1.95	0.25	0.49	0.97
	90-100	1.95	0.5	0.98	0.94
	100-110	1.95	1	1.95	3.89
	110-120	1.95	2	3.90	7.79
	120-130	0.39	4	1.56	9.35
Erosion from 1670 to 1449 Ma of 1805 m.	120-130	10.61	4	42.44	51.79
	110-120	40.8	2	81.60	133.39
	100-120	40.8	1	40.80	174.19
	90-100	40.8	0.5	20.40	194.59
	80-90	40.8	0.25	10.20	204.79
	70-80	40.8	0.125	5.10	209.89
	60-70	6.31	0.0625	0.39	210.28
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	60-70	1.72	0.0625	0.11	210.28
	70-80	11.11	0.125	1.39	211.67
	80-90	7.17	0.25	1.79	213.46
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	80-90	83.34	0.25	20.84	234.3
	70-80	129.19	0.125	16.15	250.45
	60-70	129.19	0.0625	8.07	258.52
	50-60	129.19	0.0313	4.04	262.56
	40-50	129.1	0.0156	2.01	264.57
	30-40	129.1	0.0078	1.01	265.58
	20-30	129.1	0.0039	0.50	266.08
Deposition and erosion of Cambrian and Cretaceous sediments, 570 Ma to present.	20-30	570	0.0039	2.22	268.3

Rv% for a total TTI of 268 is 1.5;

Price's (1983) method:

maximum burial = 3420 m, maximum temperature = 122.6° C, Rv% = 0.6

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M1. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 1a.

Glyde River Subbasin, model 1b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0
deposited over 20 my	30-40	0.81	0.0078	0.01	0.01
plus 820 m of	40-50	1.42	0.0156	0.02	0.03
Barney Ck. Fm.	50-60	1.95	0.0313	0.06	0.09
deposited over 2 my.	60-70	1.95	0.0625	0.12	0.21
A total of 4240 m	70-80	1.95	0.125	0.24	0.45
deposited from 1692	80-90	1.95	0.25	0.49	0.94
to 1670 Ma.	90-100	1.95	0.5	0.98	1.91
	100-110	1.95	1	1.95	3.86
	110-120	1.95	2	3.90	7.76
	120-130	1.95	4	7.80	15.56
	130-140	1.95	8	15.60	31.16
	140-150	1.40	16	22.45	53.61
Erosion from	140-150	29.38	16	470.08	523.69
1670 to 1449 Ma	130-140	40.80	8	326.40	850.09
of 1805 m.	120-130	40.80	4	163.20	1013.29
	110-120	40.80	2	81.60	1094.89
	100-110	40.80	1	40.80	1135.69
	90-100	28.35	0.5	14.18	1149.87
Deposition of 600 m	90-100	7.72	0.5	3.86	1153.73
Roper Group from	100-110	11.11	1	11.11	1164.84
1449 to 1429 Ma.	110-120	1.16	2	2.32	1167.16
Erosion to top of	110-120	13.56	2	27.12	1194.28
Barney Ck. Fm. from	100-110	129.20	1	129.20	1323.48
1429 to 570 Ma.	90-100	129.20	0.5	64.60	1388.08
	80-90	129.20	0.25	32.30	1420.38
	70-80	129.20	0.125	16.15	1436.53
	60-70	129.20	0.0625	8.08	1444.60
	50-60	129.20	0.0313	4.04	1448.64
	40-50	69.77	0.0156	1.09	1449.73
Deposition of 300 m of	40-50	6.00	0.0156	0.09	1449.82
Bukalara Sst. from	50-60	4.00	0.0313	0.13	1449.95
570 to 560 Ma.					
Erosion of 100m of	50-60	50.00	0.0313	1.57	1451.51
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	1451.57
Top Springs Lmst.					
from 510 to 508 Ma.					

Erosion of Top Springs	50-60	228.57	0.0313	7.15	1471.55
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	1474.38
Sst. (200m) to Cretaceous unconformity from 508 to 100 Ma					
Deposition of 200 m of Cretaceous	40-50	4.00	0.0156	0.06	1474.44
Mullaman Beds from 100 to 90 Ma	50-60	6.00	0.0313	0.19	1474.63
Erosion from 90 Ma to present	50-60	9.64	0.0313	0.30	1474.93
	40-50	26.79	0.0156	0.42	1475.35
	30-40	26.79	0.0078	0.21	1475.56
	20-30	26.79	0.0039	0.10	1475.66

Rv% for a total TTI of 1476 is 2.2;

Price's (1983) method:

maximum burial = 4240 m, maximum temperature = 147° C, Rv% = 0.7

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M2. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 1b.

Glyde River Subbasin, model 2a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck.	20-30	1.95	0.0039	0.01	0.01
	30-40	1.95	0.0078	0.02	0.03
Fm. from 1690 to 1670 Ma.	40-50	1.95	0.0156	0.03	0.06
	50-60	1.95	0.0313	0.06	0.12
	60-70	1.95	0.0625	0.12	0.24
	70-80	1.95	0.125	0.24	0.48
	80-90	1.95	0.25	0.49	0.97
	90-100	1.95	0.5	0.98	1.94
	100-110	1.95	1	1.95	3.89
	110-120	1.95	2	3.90	6.79
	120-130	0.39	4	1.56	8.35
Erosion from 1670 to 1449 Ma of 240 m.	120-130	79.84	4	319.36	327.71
	110-120	60.46	2	120.92	448.63
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	110-120	5.11	2	10.22	458.85
	120-130	11.11	4	44.44	503.296
	130-140	3.78	8	30.24	533.54
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	130-140	25.77	8	206.16	739.7
	120-130	75.75	4	303.00	1042.69
	110-120	75.75	2	151.50	1194.19
	100-120	75.75	1	75.75	1269.94
	90-100	75.75	0.5	37.88	1307.82
	80-90	75.75	0.25	18.94	1326.76
	70-80	75.75	0.125	9.47	1336.23
	60-70	75.75	0.0625	4.73	1340.96
	50-60	75.75	0.0313	2.37	1343.33
	40-50	75.75	0.0156	1.18	1341.51
	30-40	75.75	0.0078	0.59	1345.1
	20-30	75.75	0.0039	0.30	1345.4
Deposition and erosion of Cambrian and Cretaceous sediments.	20-30	570	0.0039	2.22	1347.62

Rv% for a total TTI of 1348 is 2.2;

Price's (1983) method:

maximum burial = 3780 m, maximum temperature = 133.4° C, Rv% = 0.7

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M3. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 2a.

Glyde River Subbasin, model 2b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck. Fm. deposited over 20 my plus 820 m of Barney Ck. Fm. deposited over 2 my. A total of 4240 m deposited from 1692 to 1670 Ma.	20-30 30-40 40-50 50-60 60-70 70-80 80-90 90-100 100-110 110-120 120-130 130-140 140-150	0.81 0.81 1.42 1.95 1.95 1.95 1.95 1.95 1.95 1.95 1.95 1.95 1.40	0.0039 0.0078 0.0156 0.0313 0.0625 0.125 0.25 0.5 1 2 4 8 16	0.00 0.01 0.02 0.06 0.12 0.24 0.49 0.98 1.95 3.90 7.80 15.60 22.45	0.00 0.01 0.03 0.09 0.21 0.45 0.94 1.91 3.86 7.76 15.56 31.16 53.61
Erosion from 1670 to 1449 Ma of 240 m.	140-150	221.00	16	3536.00	3589.62
Deposition of 600 m Roper Group from 1449 to 1429 Ma	140-150 130-140	11.11 8.99	16 8	177.76 71.92	3767.22 3839.14
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	140-150 130-140 120-130 110-120 100-110 90-100 80-90 70-80 60-70 50-60 40-50	60.61 75.76 75.76 75.76 75.76 75.76 75.76 75.76 75.76 75.76 40.91	16 8 4 2 1 0.5 0.25 0.125 0.0625 0.0313 0.0156	969.76 606.08 303.04 151.52 75.76 37.88 18.94 9.47 4.74 2.37 0.64	4808.90 5414.98 5718.02 5869.54 5945.30 5983.18 6002.12 6011.59 6016.33 6018.70 6019.34
Deposition of 300 m of Bukalara Sst. from 570-560 Ma.	40-50 50-60	6.00 4.00	0.0156 0.0313	0.09 0.13	6019.43 6019.56
Erosion of 100m of Bukalara Sst. from 560-510 Ma.	50-60	50.00	0.0313	1.57	6021.12
Deposition of 100 m of Top Springs Lmst. from 510-508 Ma.	50-60	2.00	0.0313	0.06	6021.18

Erosion of Top Springs	50-60	228.57	0.0313	7.15	6028.33
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	6031.16
Sst. (200m) to Cret. unconformity from 508 to 100 Ma.					
Deposition of 200 m of Cretaceous	40-50	4.00	0.0156	0.06	6031.22
Mullaman Beds from 100 to 90 Ma.	50-60	6.00	0.0313	0.19	6031.41
Erosion from 90 Ma to present.	50-60	9.64	0.0313	0.30	6031.71
	40-50	26.79	0.0156	0.42	6032.13
	30-40	26.79	0.0078	0.21	6032.34
	20-30	26.79	0.0039	0.10	6032.44

Rv% for a total TTI of 6032 is 3.0;

Price's (1983) method:

maximum burial = 4600 m, maximum temperature = 158° C, Rv% = 0.8

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M4. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 2b.

Glyde River Subbasin, model 3a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck.	20-30	22.51	0.0039	0.09	0.09
	30-40	22.51	0.0078	0.18	0.27
Fm. from 1690 to 1459 Ma.	40-50	22.51	0.0156	0.35	0.62
	50-60	22.51	0.0313	0.70	1.32
	60-70	22.51	0.0625	1.41	2.73
	70-80	22.51	0.125	2.81	5.54
	80-90	22.51	0.25	5.63	11.17
	90-100	22.51	0.5	11.26	22.43
	100-110	22.51	1	22.51	44.94
	110-120	22.51	2	45.02	89.96
	120-130	5.85	4	23.40	113.36
Erosion from 1459 to 1449 Ma	120-130	0.64	4	2.56	115.92
of 1805 m.	110-120	1.85	2	3.70	119.62
	100-120	1.85	1	1.85	121.47
	90-100	1.85	0.5	0.93	122.40
	80-90	1.85	0.25	0.46	122.86
	70-80	1.85	0.125	0.23	123.09
	60-70	0.29	0.0625	0.02	123.11
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	60-70	1.72	0.0625	0.11	123.22
	70-80	11.11	0.125	1.39	124.61
	80-90	7.17	0.25	1.79	126.40
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	80-90	83.34	0.25	20.84	147.24
	70-80	129.19	0.125	16.15	163.39
	60-70	129.19	0.0625	8.07	171.46
	50-60	129.19	0.0313	4.04	175.50
	40-50	129.10	0.0156	2.01	177.51
	30-40	129.10	0.0078	1.01	178.52
	20-30	129.10	0.0039	0.50	179.02
Deposition and erosion of Cambrian and Cretaceous sediments, 570 Ma to present.	20-30	570.00	0.0039	2.22	181.24

Rv% for a total TTI of 181 is 1.4;

Price's (1983) method:

maximum burial = 3420 m, maximum temperature = 122.6° C, Rv% = 0.6

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M5. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 3a.

Glyde River Subbasin, model 3b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
	30-40	0.81	0.0078	0.01	0.01
deposited over 231 my	40-50	12.78	0.0156	0.20	0.21
plus 820 m of	50-60	22.51	0.0313	0.70	0.91
Barney Ck. Fm.	60-70	22.51	0.0625	1.41	2.32
deposited over 2 my.	70-80	22.51	0.125	2.81	5.13
A total of 4240 m	80-90	22.51	0.25	5.63	10.76
deposited from 1692	90-100	22.51	0.5	11.26	22.02
to 1459 Ma.	100-110	22.51	1	22.51	44.53
	110-120	22.51	2	45.02	89.55
	120-130	22.51	4	90.04	179.59
	130-140	22.51	8	180.08	359.67
	140-150	16.21	16	259.36	619.03
Erosion from	140-150	1.33	16	21.28	640.31
1670-1449 Ma	130-140	1.85	8	14.80	655.11
of 1805 m.	120-130	1.85	4	7.40	662.51
	110-120	1.85	2	3.70	666.21
	100-120	1.85	1	1.85	668.06
	90-100	1.28	0.5	0.64	668.70
Deposition of 600 m	90-100	7.72	0.5	3.86	672.56
Roper Group from	100-110	11.11	1	11.11	683.67
1449 to 1429 Ma.	110-120	1.16	2	2.32	685.99
Erosion to top of	110-120	13.56	2	27.12	713.11
Barney Ck. Fm. from	100-110	129.20	1	129.20	842.31
1429 to 570 Ma.	90-100	129.20	0.5	64.60	906.91
	80-90	129.20	0.25	32.30	939.21
	70-80	129.20	0.125	16.15	955.36
	60-70	129.20	0.0625	8.08	963.43
	50-60	129.20	0.0313	4.04	967.47
	40-50	69.77	0.0156	1.09	968.56
Deposition of 300 m of	40-50	6.00	0.0156	0.09	968.65
Bukalara Sst. from	50-60	4.00	0.0313	0.13	968.78
570 to 560 Ma.					
Erosion of 100m of	50-60	50	0.0313	1.57	970.34
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	970.40
Top Springs Lmst.					
from 510 to 508 Ma.					

Erosion of Top Springs	50-60	228.57	0.0313	7.15	977.55
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	980.38
Sst. (200m) to Cret. unconformity from 508 to 100 Ma.					
Deposition of 200 m of Cretaceous	40-50	4.00	0.0156	0.06	980.44
Mullaman Beds from 100 - 90 Ma.	50-60	6.00	0.0313	0.19	980.63
Erosion from 90 Ma to present.	50-60	9.64	0.0313	0.30	980.93
	40-50	26.79	0.0156	0.42	981.35
	30-40	26.79	0.0078	0.21	981.56
	20-30	26.79	0.0039	0.10	981.66

Rv% for a total TTI of

Rv% for a total TTI of 882 is 2.0;

Price's (1983) method:

maximum burial = 4240 m, maximum temperature = 147° C, Rv% = 0.7

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M6. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 3b.

Glyde River Subbasin, model 4a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck.	20-30	22.51	0.0039	0.09	0.09
	30-40	22.51	0.0078	0.18	0.27
Fm. from 1690 to 1459 Ma.	40-50	22.51	0.0156	0.35	0.62
	50-60	22.51	0.0313	0.70	1.32
	60-70	22.51	0.0625	1.41	2.73
	70-80	22.51	0.125	2.81	5.54
	80-90	22.51	0.25	5.63	11.17
	90-100	22.51	0.5	11.26	22.43
	100-110	22.51	1	22.51	44.94
	110-120	22.51	2	45.02	89.96
	120-130	5.85	4	23.40	113.36
Erosion from 1459 to 1449 Ma	120-130	3.58	4	14.32	127.68
of 240 m.	110-120	6.42	2	12.84	140.52
Deposition of 600 m Roper Group from	110-120	5.11	2	10.22	150.74
1449 to 1429 Ma.	120-130	1.11	4	4.44	155.18
	130-140	3.78	8	30.24	185.42
Erosion to top of Barney Ck. Fm. from	130-140	25.77	8	206.16	391.58
1429 to 570 Ma.	120-130	75.75	4	303.00	694.58
	110-120	75.75	2	151.50	846.08
	100-120	75.75	1	75.75	921.83
	90-100	75.75	0.5	37.88	959.71
	80-90	75.75	0.25	18.94	978.65
	70-80	75.75	0.125	9.47	988.12
	60-70	75.75	0.0625	4.73	992.85
	50-60	75.75	0.0313	2.37	995.22
	40-50	75.75	0.0156	1.18	996.40
	30-40	75.75	0.0078	0.59	996.99
	20-30	75.75	0.0039	0.30	997.29
Deposition and erosion of Cambrian and Cretaceous sediments.	20-30	570.00	0.0039	2.22	999.51

Rv% for a total TTI of 1000 is 2.0;

Price's (1983) method:

maximum burial = 3780 m, maximum temperature = 133.4° C, Rv% = 0.7.

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M7. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 4a.

Glyde River Subbasin, model 4b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 3420 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
deposited over 231 my	30-40	0.81	0.0078	0.01	0.01
plus 820 m of	40-50	12.78	0.0156	0.20	0.21
Barney Ck. Fm.	50-60	22.51	0.0313	0.70	0.91
deposited over 2 my.	60-70	22.51	0.0625	1.41	2.32
A total of 4240 m	70-80	22.51	0.125	2.81	5.13
deposited from 1692	80-90	22.51	0.25	5.63	10.76
to 1459 Ma.	90-100	22.51	0.5	11.26	22.02
	100-110	22.51	1	22.51	44.53
	110-120	22.51	2	45.02	89.55
	120-130	22.51	4	90.04	179.59
	130-140	22.51	8	180.08	359.67
	140-150	16.21	16	259.36	619.03
Erosion from 1459 to 1449 Ma of 240 m.	140-150	10.00	16	160.00	779.03
Deposition of 600 m Roper Group from	140-150	11.11	16	177.76	956.78
1449 to 1429 Ma.	130-140	8.99	8	71.92	1028.71
Erosion to top of Barney Ck. Fm. from	140-150	60.61	16	969.76	1998.47
1429 to 570 Ma.	130-140	75.76	8	606.08	2604.55
	120-130	75.76	4	303.04	2907.59
	110-120	75.76	2	151.52	3059.11
	100-110	75.76	1	75.76	3135.87
	90-100	75.76	0.5	37.88	3173.75
	80-90	75.76	0.25	18.94	3192.69
	70-80	75.76	0.125	9.47	3202.16
	60-70	75.76	0.0625	4.74	3206.90
	50-60	75.76	0.0313	2.37	3209.27
	40-50	40.91	0.0156	0.64	3209.91
Deposition of 300 m of Bukalara Sst. from	40-50	6.00	0.0156	0.09	3210.00
570-560 Ma.	50-60	4.00	0.0313	0.13	3210.13
Erosion of 100m of Bukalara Sst. from	50-60	50.00	0.0313	1.57	3211.69
560-510 Ma.					
Deposition of 100 m of Top Springs Lmst. from 510-508 Ma.	50-60	2.00	0.0313	0.06	3211.75

Erosion of Top Springs	50-60	228.57	0.0313	7.15	3218.90
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	3221.73
Sst. (200m) to Cret. unconformity from 508 to 100 Ma.					
Deposition of 200 m of Cretaceous	40-50	4.00	0.0156	0.06	3221.79
Mullaman Beds from 100 to 90 Ma.	50-60	6.00	0.0313	0.19	3221.98
Erosion from 90 Ma to present.	50-60	9.64	0.0313	0.30	3222.28
	40-50	26.79	0.0156	0.42	3222.70
	30-40	26.79	0.0078	0.21	3222.91
	20-30	26.79	0.0039	0.10	3223.01

Rv% for a total TTI of 3223 is 2.6;

Price's (1983) method:

maximum burial = 4460 m, maximum temperature = 158° C, Rv% = 0.8

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M8. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 4b.

Glyde River Subbasin, model 5a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck.	20-30	3.33	0.0039	0.01	0.01
	30-40	3.33	0.0078	0.03	0.04
Fm. from 1690 to 1670 Ma.	40-50	3.33	0.0156	0.05	0.09
	50-60	3.33	0.0313	0.10	0.19
	60-70	3.33	0.0625	0.21	0.40
	70-80	3.33	0.125	0.42	0.82
Erosion from 1670-1449 Ma	70-80	40.85	0.125	5.11	5.93
	60-70	40.85	0.0625	2.55	8.48
of 1805 m.	50-60	40.85	0.0313	1.28	10.28
	40-50	40.85	0.0156	0.64	10.92
	30-40	40.85	0.0078	0.32	11.24
	20-30	16.70	0.0039	0.07	11.31
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	20-30	4.60	0.0039	0.02	11.33
	30-40	11.11	0.0078	0.09	11.42
	40-50	4.29	0.0156	0.07	11.49
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	40-50	138.06	0.0156	2.15	13.64
	30-40	358.42	0.0078	2.80	16.44
	20-30	358.42	0.0039	1.40	17.84
Deposition and erosion of Cambrian and Cretaceous sediments, 570 Ma to present.	20-30	570.00	0.0039	2.22	20.06

Rv% for a total TTI of 20 is 0.7;

Price's (1983) method:

maximum burial = 2000 m, maximum temperature = 80° C, Rv% = 0.4.

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M9. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 5a.

Glyde River Subbasin, model 5b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
deposited over 20 my	30-40	0.81	0.0078	0.01	0.01
plus 820 m of	40-50	3.17	0.0156	0.05	0.06
Barney Ck. Fm.	50-60	3.30	0.0313	0.10	0.16
deposited over 2 my.	60-70	3.30	0.0625	0.21	0.37
A total of 2820 m	70-80	3.30	0.125	0.41	0.78
deposited from 1692	80-90	3.30	0.25	0.83	1.60
to 1670 Ma.	90-100	3.30	0.5	1.65	3.25
	100-110	1.80	1	1.80	5.05
Erosion from	100-110	18.78	1	18.78	23.83
1670-1449 Ma	90-100	40.80	0.5	20.40	44.23
of 1805 m.	80-90	40.80	0.25	10.20	54.43
	70-80	40.80	0.125	5.10	59.53
	60-70	40.80	0.0625	2.55	62.08
	50-60	38.96	0.0313	1.22	63.30
Deposition of 600 m	50-60	10.61	0.0313	0.33	63.63
Roper Group from	60-70	9.39	0.0625	0.59	64.22
1449 to 1429 Ma.					
Erosion to top of	60-70	302.90	0.0625	18.93	83.15
Barney Ck. Fm. from	50-60	358.39	0.0313	11.22	94.37
1429 to 570 Ma.	40-50	193.54	0.0156	3.02	97.39
Deposition of 300 m of	40-50	6.00	0.0156	0.09	97.48
Bukalara Sst. from	50-60	4.00	0.0313	0.13	97.61
570 to 560 Ma.					
Erosion of 100m of	50-60	50.00	0.0313	1.57	99.17
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	99.23
Top Springs Lmst.					
from 510 to 508 Ma.					
Erosion of Top Springs	50-60	228.57	0.0313	7.15	106.38
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	109.21
Sst. (200m) to Cret.					
unconformity from					
508 to 100 Ma.					

Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	40-50	4.00	0.0156	0.06	109.27
	50-60	6.00	0.0313	0.19	109.46
Erosion from 90 Ma to present.	50-60	9.64	0.0313	0.30	109.76
	40-50	26.79	0.0156	0.42	110.18
	30-40	26.79	0.0078	0.21	110.39
	20-30	26.79	0.0039	0.10	110.49

Rv% for a total TTI of 110 is 1.2;

Price's (1983) method:

maximum burial = 2820 m, maximum temperature = 105° C, Rv% = 0.5

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M10. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 5b.

Glyde River Subbasin, model 6a	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm. from 1690 to 1670 Ma.	20-30	3.33	0.0039	0.01	0.01
	30-40	3.33	0.0078	0.03	0.04
	40-50	3.33	0.0156	0.05	0.09
	50-60	3.33	0.0313	0.10	0.19
	60-70	3.33	0.0625	0.21	0.40
	70-80	3.33	0.125	0.42	0.82
Erosion from 1670 to 1449 Ma of 240 m.	70-80	221.00	0.125	27.63	28.44
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	70-80	8.00	0.125	1.00	29.44
	80-90	11.10	0.25	2.78	32.21
	90-100	0.89	0.5	0.45	32.66
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	90-100	9.70	0.5	4.85	37.51
	80-90	121.21	0.25	30.30	67.81
	70-80	121.21	0.125	15.15	82.96
	60-70	121.21	0.0625	7.58	90.54
	50-60	121.21	0.0313	3.79	94.33
	40-50	121.21	0.0156	1.89	96.22
	30-40	121.21	0.0078	0.95	97.17
	20-30	121.21	0.0039	0.47	97.64
Deposition and erosion of Cambrian and Cretaceous sediments.	20-30	570.00	0.0039	2.22	99.86

Rv% for a total TTI of 100 is 1.1;

Price's (1983) method:

maximum burial = 2360 m, maximum temperature = 90.8° C, Rv% = 0.5

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M11. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 6a.

Glyde River Subbasin, model 6b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
	30-40	0.81	0.0078	0.01	0.01
deposited over 20 my	40-50	3.17	0.0156	0.05	0.06
plus 820 m of	50-60	3.30	0.0313	0.10	0.16
Barney Ck. Fm.	60-70	3.30	0.0625	0.21	0.37
deposited over 2 my.	70-80	3.30	0.125	0.41	0.78
A total of 2820 m	80-90	3.30	0.25	0.83	1.60
deposited from 1692	90-100	3.30	0.5	1.65	3.25
to 1670 Ma.	100-110	1.80	1	1.80	5.05
Erosion from	100-110	153.40	1	153.40	158.45
1670 to 1449 Ma	90-100	86.60	0.5	43.30	201.75
of 240 m.					
Deposition of 600 m	90-100	2.89	0.5	1.45	203.20
Roper Group from	100-110	11.11	1	11.11	214.31
1449 to 1429 Ma	110-120	6.00	2	12.00	226.31
Erosion to top of	110-120	65.45	2	130.90	357.21
Barney Ck. Fm. from	100-110	121.21	1	121.21	478.42
1429 to 570 Ma.	90-100	121.21	0.5	60.61	539.02
	80-90	121.21	0.25	30.30	569.32
	70-80	121.21	0.125	15.15	584.47
	60-70	121.21	0.0625	7.58	592.05
	50-60	121.21	0.0313	3.79	595.84
	40-50	65.45	0.0156	1.02	596.86
Deposition of 300 m of	40-50	6.00	0.0156	0.09	596.95
Bukalara Sst. from	50-60	4.00	0.0313	0.13	597.08
570 to 560 Ma.					
Erosion of 100 m of	50-60	50.00	0.0313	1.57	598.64
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	598.70
Top Springs Lmst.					
from 510 to 508 Ma.					
Erosion of Top Springs	50-60	228.57	0.0313	7.15	605.85
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	608.68
Sst. (200m) to Cret.					
unconformity from					
508 to 100 Ma.					

Deposition of 200 m	40-50	4.00	0.0156	0.06	608.74
of Cretaceous	50-60	6.00	0.0313	0.19	608.93
Mullaman Beds from					
100 to 90 Ma.					
Erosion from 90 Ma	50-60	9.64	0.0313	0.30	609.23
to present.	40-50	26.79	0.0156	0.42	609.65
	30-40	26.79	0.0078	0.21	609.86
	20-30	26.79	0.0039	0.10	609.96

Rv% for a total TTI of 610 is 1.8;

Price's (1983) method:

maximum burial = 3180 m, maximum temperature = 115° C, Rv% = 0.6

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M12. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 6b.

Glyde River Subbasin, model 7a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm. from 1690 to 1459 Ma.	20-30	40.16	0.0039	0.16	0.16
	30-40	40.16	0.0078	0.31	0.47
	40-50	40.16	0.0156	0.63	1.10
	50-60	40.16	0.0313	1.26	2.36
	60-70	40.16	0.0625	2.51	4.87
	70-80	40.16	0.125	5.02	9.89
Erosion from 1459-1449 Ma of 1805 m.	70-80	1.85	0.125	0.23	10.12
	60-70	1.85	0.0625	0.12	10.24
	50-60	1.85	0.0313	0.06	10.30
	40-50	1.85	0.0156	0.03	10.33
	30-40	1.85	0.0078	0.01	10.34
	20-30	0.77	0.0039	0.00	10.34
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	20-30	4.61	0.0039	0.02	10.36
	30-40	11.11	0.0078	0.09	10.45
	40-50	4.28	0.0156	0.07	10.52
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	40-50	138.06	0.0156	2.15	12.67
	30-40	358.42	0.0078	2.80	15.47
	20-30	358.42	0.0039	1.40	16.87
Deposition and erosion of Cambrian and Cretaceous sediments, 570 Ma to present.	20-30	570.00	0.0039	2.22	19.09

Rv% for a total TTI of 19 is 0.7;

Price's (1983) method:

maximum burial = 2000 m, maximum temperature = 80° C, Rv% = 0.4

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M13. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 7a.

Glyde River Subbasin, model 7b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
deposited over 231 my	30-40	0.81	0.0078	0.01	0.01
plus 820 m of	40-50	21.16	0.0156	0.33	0.34
Barney Ck. Fm.	50-60	38.49	0.0313	1.20	1.54
deposited over 2 my.	60-70	38.49	0.0625	2.41	3.95
A total of 2820 m	70-80	38.49	0.125	4.81	8.76
deposited from 1692	80-90	38.49	0.25	9.62	18.38
to 1459 Ma.	90-100	38.49	0.5	19.25	37.63
	100-110	27.71	1	27.71	65.34
Erosion from	100-110	0.85	1	0.85	66.19
1459 -1449 Ma	90-100	1.84	0.5	0.92	67.11
of 1805 m.	80-90	1.84	0.25	0.46	67.57
	70-80	1.84	0.125	0.23	67.80
	60-70	1.84	0.0625	0.12	67.92
	50-60	0.08	0.0313	0.00	67.92
Deposition of 600 m	50-60	10.61	0.0313	0.33	68.15
Roper Group from	60-70	9.39	0.0625	0.59	68.84
1449 to 1429 Ma					
Erosion to top of	60-70	302.9	0.0625	18.93	87.77
Barney Ck. Fm. from	50-60	358.39	0.0313	11.22	98.99
1429 to 570 Ma.	40-50	193.54	0.0156	3.02	102.01
Deposition of 300 m of	40-50	6.00	0.0156	0.09	102.10
Bukalara Sst. from	50-60	4.00	0.0313	0.13	102.23
570 to 560 Ma.					
Erosion of 100m of	50-60	50.00	0.0313	1.57	103.79
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	103.85
Top Springs Lmst.					
from 510-508 Ma.					
Erosion of Top Springs	50-60	228.57	0.0313	7.15	111.00
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	113.83
Sst. (200m) to Cret.					
unconformity from					
508 to 100 Ma.					

Deposition of 200 m	40-50	4.00	0.0156	0.06	113.89
of Cretaceous	50-60	6.00	0.0313	0.19	114.08
Mullaman Beds from					
100 to 90 Ma.					
Erosion from 90 Ma	50-60	9.64	0.0313	0.30	114.38
to present.	40-50	26.79	0.0156	0.42	114.80
	30-40	26.79	0.0078	0.21	115.01
	20-30	26.79	0.0039	0.10	115.11

Rv% for a total TTI of 115 is 1.2;

Price's (1983) method:

maximum burial = 2820 m, maximum temperature = 105° C, Rv% = 0.5

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M14. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 7b.

Glyde River Subbasin, model 8a.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm. from 1690 to 1459 Ma.	20-30	40.16	0.0039	0.16	0.16
	30-40	40.16	0.0078	0.31	0.47
	40-50	40.16	0.0156	0.63	1.10
	50-60	40.16	0.0313	1.26	2.36
	60-70	40.16	0.0625	2.51	4.87
	70-80	40.16	0.125	5.02	9.89
Erosion from 1459 to 1449 Ma of 240 m.	70-80	10.00	0.125	1.25	11.14
Deposition of 600 m Roper Group from 1449 to 1429 Ma.	70-80	8.00	0.125	1.00	12.14
	80-90	11.10	0.25	2.78	14.92
	90-100	0.89	0.5	0.45	15.37
Erosion to top of Barney Ck. Fm. from 1429 to 570 Ma.	90-100	9.70	0.5	4.85	20.22
	80-90	121.21	0.25	30.30	50.52
	70-80	121.21	0.125	15.15	65.67
	60-70	121.21	0.0625	7.58	73.25
	50-60	121.21	0.0313	3.79	77.04
	40-50	121.21	0.0156	1.89	78.93
	30-40	121.21	0.0078	0.95	79.88
	20-30	121.21	0.0039	0.47	80.35
Deposition and erosion of Cambrian and Cretaceous sediments.	20-30	570.00	0.0039	2.22	82.57

Rv% for a total TTI of 83 is 1.0;

Price's (1983) method:

maximum burial = 2360 m, maximum temperature = 90.8° C, Rv% = 0.5

Observed equivalent Rv% for the top of the Barney Creek Fm. in the Glyde River Subbasin is 0.5 to 0.7.

Appendix M15. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near top of Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 8a.

Glyde River Subbasin, model 8b.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition of 2000 m above Barney Ck. Fm.	20-30	0.81	0.0039	0.00	0.00
	30-40	0.81	0.0078	0.01	0.01
deposited over 231 my	40-50	21.16	0.0156	0.33	0.34
plus 820 m of	50-60	38.49	0.0313	1.20	1.54
Barney Ck. Fm.	60-70	38.49	0.0625	2.41	3.95
deposited over 2 my.	70-80	38.49	0.125	4.81	8.76
A total of 2820 m	80-90	38.49	0.25	9.62	18.38
deposited from 1692	90-100	38.49	0.5	19.25	37.63
to 1459 Ma.	100-110	27.71	1	27.71	65.34
Erosion from	100-110	6.39	1	6.39	71.73
1459 -1449 Ma	90-100	3.61	0.5	1.81	73.53
of 240 m.					
Deposition of 600 m	90-100	2.89	0.5	1.45	74.98
Roper Group from	100-110	11.11	1	11.11	86.09
1449 to 1429 Ma.	110-120	6.00	2	12.00	98.09
Erosion to top of	110-120	65.45	2	130.90	228.99
Barney Ck. Fm. from	100-110	121.21	1	121.21	350.20
1429 to 570 Ma.	90-100	121.21	0.5	60.61	410.80
	80-90	121.21	0.25	30.30	441.10
	70-80	121.21	0.125	15.15	456.25
	60-70	121.21	0.0625	7.58	463.83
	50-60	121.21	0.0313	3.79	467.62
	40-50	65.45	0.0156	1.02	468.64
Deposition of 300 m of	40-50	6.00	0.0156	0.09	468.73
Bukalara Sst. from	50-60	4.00	0.0313	0.13	468.86
570-560 Ma.					
Erosion of 100 m of	50-60	50.00	0.0313	1.57	470.42
Bukalara Sst. from					
560 to 510 Ma.					
Deposition of 100 m of	50-60	2.00	0.0313	0.06	470.48
Top Springs Lmst.					
from 510 to 508 Ma.					
Erosion of Top Springs	50-60	228.57	0.0313	7.15	477.63
Lmst. and Bukalara	40-50	181.43	0.0156	2.83	480.46
Sst. (200m) to Cret.					
unconformity from					
508 to 100 Ma.					

Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	40-50	4.00	0.0156	0.06	480.52
	50-60	6.00	0.0313	0.19	480.71
Erosion from 90 Ma to present.	50-60	9.64	0.0313	0.30	481.01
	40-50	26.79	0.0156	0.42	481.43
	30-40	26.79	0.0078	0.21	481.64
	20-30	26.79	0.0039	0.10	481.74

Rv% for a total TTI of 481 is 1.7;

Price's (1983) method:

maximum burial = 3180 m, maximum temperature = 115° C, Rv% = 0.6

Observed equivalent Rv% for near the base of the Barney Creek Fm. in the Glyde River Subbasin (DDH GR7 at 854 m) = 1.0.

Appendix M16. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Near base of DDH GR7, Barney Creek Formation, Glyde River Subbasin, depositional-erosional model 8b.

BROADMERE 1, base of well, Mainoru Formation.	Temperature Interval (°C)	Time (my)	Temperature factor	Interval TTI	Total TTI
Deposition from 1529 to 1429 Ma of 2174 m observed thickness of Roper Group at Broadmere 1 plus an additional estimated 1548 m of Maiwok Sub-Group.	20-30	8.95	0.0039	0.03	0.03
	30-40	8.95	0.0078	0.07	0.10
	40-50	8.95	0.0156	0.14	0.24
	50-60	8.95	0.0313	0.28	0.52
	60-70	8.95	0.0625	0.56	1.08
	70-80	8.95	0.125	1.12	2.20
	80-90	8.95	0.25	2.24	4.44
	90-100	8.95	0.5	4.48	8.92
	100-110	8.95	1	8.95	17.87
	110-120	8.95	2	17.90	35.77
	120-130	8.95	4	35.80	71.57
	130-140	1.48	8	11.84	83.41
Erosion of an estimated 500 m of Roper Group from 1429-1280 Ma.	130-140	16.37	8	130.96	214.37
	120-130	99.21	4	396.84	611.21
	110-120	32.58	2	65.16	676.37
Intrusion of a total of 300m of dolerite sills at 1280 Ma followed by erosion of 1248m of Roper Group to 570 Ma.	130-120	159.09	4	636.36	1312.73
	120-110	189.39	2	378.78	1691.51
	110-100	189.39	1	189.39	1880.90
	100-90	189.39	0.5	94.70	1975.60
	90-80	57.17	0.25	14.29	1989.89
Deposition of 300 m of Bukalara Sandstone from 570 to 560 Ma.	80-90	1.14	0.25	0.29	1990.18
	90-100	8.86	0.5	4.43	1994.61
Erosion of Bukalara Sandstone of 100 m from 560 to 510 Ma.	90-100	50.00	0.5	25.00	2019.61
Deposition of 100 m of Top Springs Limestone from 510 to 508 Ma.	90-100	2.00	0.5	1.00	2020.61
Erosion of Top Springs Limestone Bukalara Sandstone and Roper Group of 370 m from 508 to 100 Ma (present top of well is 30 m below the Cretaceous unconformity).	90-100	219.01	0.50	109.55	2130.16
	80-90	188.99	0.25	47.25	2177.41
Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	80-90	6.47	0.25	1.62	2179.03
	90-100	3.53	0.50	1.77	2180.80
Erosion of 200 m of Mullaman Beds and 30 m of Roper Group from 90 Ma to present.	90-100	70.70	0.50	35.35	2216.15
	80-90	129.30	0.25	42.33	2258.48

TTI of 2258 = 2.4 Rv%;

Price's (1983) method: maximum burial = 3722 m; maximum temperature = 132° C;

Rv% = 0.6. Observed equivalent Rv near base of well = 3.5%.

Appendix M17. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Mainoru Formation, Roper Group, Broadmere 1 well, depositional-erosional model 1.

BROADMERE 1, base of well, Mainoru Formation.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition from 1449 to 1429 Ma of 2174 m observed thickness of Roper Group at Broadmere 1 plus an additional estimated 1548 m of Maiwok Sub-Group.	20-30	1.79	0.0039	0.01	0.01
	30-40	1.79	0.0078	0.01	0.02
	40-50	1.79	0.0156	0.03	0.05
	50-60	1.79	0.0313	0.06	0.11
	60-70	1.79	0.0625	0.11	0.22
	70-80	1.79	0.125	0.22	0.44
	80-90	1.79	0.25	0.45	0.89
	90-100	1.79	0.5	0.90	1.79
	100-110	1.79	1	1.79	3.58
	110-120	1.79	2	3.58	7.16
	120-130	1.79	4	7.16	14.32
	130-140	0.30	8	2.40	16.72
Erosion of an estimated 500 m of Roper Group from 1429-1280 Ma.	130-140	16.37	8	130.96	147.68
	120-130	99.21	4	396.84	544.52
	110-120	32.58	2	65.16	609.68
Intrusion of a total of 300m of dolerite sills at 1280 Ma followed by erosion of 1248m of Roper Group to 570 Ma.	130-120	159.09	4	636.36	1246.04
	120-110	189.39	2	378.78	1624.82
	110-100	189.39	1	189.39	1814.21
	100-90	189.39	0.5	94.70	1908.91
	90-80	57.17	0.25	14.29	1923.20
Deposition of 300 m of Bukalara Sandstone from 570 to 560 Ma.	80-90	1.14	0.25	0.29	1923.69
	90-100	8.86	0.5	4.43	1928.12
Erosion of Bukalara Sandstone of 100 m from 560 to 510 Ma.	90-100	50.00	0.5	25.00	1953.12
Deposition of 100 m of Top Springs Limestone from 510 to 508 Ma.	90-100	2.00	0.5	1.00	1954.12
Erosion of Top Springs Limestone Bukalara Sandstone and Roper Group of 370 m from 508 to 100 Ma (present top of well is 30 m below the Cretaceous unconformity).	90-100	219.01	0.50	109.55	2063.67
	80-90	188.99	0.25	47.25	2110.92
Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	80-90	6.47	0.25	1.62	2112.54
	90-100	3.53	0.50	1.77	2114.31
Erosion of 200 m of Mullaman Beds and 30 m of Roper Group from 90 Ma to present.	90-100	70.7	0.50	35.35	2149.66
	80-90	129.3	0.25	42.33	2191.99

TTI of 2191 = 2.4 Rv%;

Price's (1983) method: maximum burial = 3722 m; maximum temperature = 132° C;

Rv% = 0.6. Observed equivalent Rv near base of well = 3.5%.

Appendix M18. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Mainoru Formation, Roper Group, Broadmere 1 well, depositional-erosional model 2.

BROADMERE 1, base of Cobanbarini Fm.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition from 1439.74 to 1429 Ma of 452 m observed thickness	20-30	1.79	0.0039	0.01	0.01
	30-40	1.79	0.0078	0.01	0.02
Cobanbarini Fm. plus	40-50	1.79	0.0156	0.03	0.05
an additional estimated 1548 m	50-60	1.79	0.0313	0.06	0.11
of Maiwok Sub-Group.	60-70	1.79	0.0625	0.11	0.22
	70-80	1.79	0.125	0.22	0.44
Erosion of an estimated 500 m	80-70	99.21	0.125	12.40	12.84
of Roper Group from 1429-1280 Ma.	70-60	49.79	0.0625	3.11	15.95
Intrusion of a total of 126 m of dolerite sills at 1280 Ma	70-60	192.76	0.0625	12.05	28.00
	60-50	219.30	0.0313	6.86	34.86
followed by erosion of 1248m	50-40	219.30	0.0156	3.42	38.18
of Roper Group to 570 Ma.	40-30	78.64	0.0078	0.61	38.79
Deposition of 300 m of Bukalara Sandstone from 570 to 560 Ma.	30-40	3.95	0.0078	0.03	38.82
	40-50	6.05	0.0156	0.09	38.91
Erosion of Bukalara Sandstone of 100 m from 560 to 510 Ma.	40-50	50.00	0.0156	0.78	39.69
Deposition of 100 m of Top Springs Limestone from 510 to 508 Ma.	40-50	2.00	0.0156	0.03	39.72
Erosion of Top Springs Limestone	40-50	199.30	0.0156	3.11	42.83
Bukalara Sandstone and Roper Group	30-40	208.70	0.0078	1.63	44.46
of 370 m from 508 to 100 Ma (present top of well is 30 m below the Cretaceous unconformity).					
Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	30-40	9.43	0.0078	0.07	44.53
	40-50	0.57	0.0156	0.01	44.54
Erosion of 200 m of Mullaman Beds and 30 m of Roper Group from 90 Ma to present.	40-50	4.45	0.0156	0.07	44.61
	30-40	85.55	0.0078	0.67	45.28

TTI of 45 = 0.9 Rv%;

Price's (1983) method: maximum burial = 2000 m; maximum temperature = 80° C;
Rv% = 0.5. Observed equivalent Rv at the base of the Cobanbarini Fm. = 1.4%.

Appendix M19. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Cobanbarini Formation, Roper Group, Broadmere 1 well, depositional-erosional model 3.

BROADMERE 1, base of Cobanbarini Fm.	Temperature range (°C)	Time (m.y.)	Temperature factor	Interval TTI	Total TTI
Deposition from 1439.74 to 1429 Ma of 452 m observed thickness	20-30	1.41	0.0039	0.00	0.01
Cobanbarini Fm. plus	30-40	1.41	0.0078	0.01	0.02
an additional estimated 2548 m	40-50	1.41	0.0156	0.02	0.05
of Maiwok Sub-Group	50-60	1.41	0.0313	0.06	0.11
	60-70	1.41	0.0625	0.09	0.22
	70-80	1.41	0.1250	0.18	0.44
	80-90	1.41	0.2500	0.35	1.00
	90-100	1.41	0.5000	0.75	2.11
	100-110	1.41	1.0000	1.41	4.33
Erosion of an estimated 500 m	110-100	99.21	1	99.21	103.54
of Roper Group from 1429-1280 Ma.	100-90	49.79	0.5	24.40	127.94
Intrusion of a total of 126 m of dolerite sills at 1280 Ma	100-90	192.76	0.5	96.38	224.32
followed by erosion of 1248m	90-80	219.30	0.25	54.82	279.15
of Roper Group to 570 Ma.	80-70	219.30	0.125	27.40	306.55
	70-60	78.64	0.0625	4.92	333.95
Deposition of 300 m of Bukalara Sandstone from 570 to 560 Ma.	60-70	10.00	0.0625	0.63	334.58
Erosion of Bukalara Sandstone of 100 m from 560 to 510 Ma.	70-60	50.00	0.0625	3.13	337.71
Deposition of 100 m of Top Springs Limestone from 510 to 508 Ma.	60-70	2.00	0.0625	0.13	337.84
Erosion of Top Springs Limestone	70-60	114.94	0.0625	7.18	345.02
Bukalara Sandstone and Roper Group	60-50	114.94	0.0313	3.59	348.61
from 508 to 100 Ma to 482m	50-40	114.94	0.0156	1.79	349.40
(present top of well is 30 m below the Cretaceous unconformity.)	40-30	63.98	0.0078	0.50	349.50
Deposition of 200 m of Cretaceous Mullaman Beds from 100 to 90 Ma.	30-40	9.43	0.0078	0.07	349.57
	40-50	0.57	0.0156	0.01	349.58
Erosion of 200 m of Mullaman Beds	40-50	4.45	0.0156	0.07	349.65
and 30 m of Roper Group from	30-40	85.55	0.0078	0.67	350.32
90 Ma to present.					

TTI of 350 = 1.6 Rv%;

Price's (1983) method: maximum burial = 3000 m; maximum temperature = 110° C;

Rv% = 0.6. Observed equivalent Rv at the base of the Cobanbarini Fm. = 1.4%.

Appendix M20. Calculations following Waples' (1981) method and Price's (1983) method, assuming a constant geothermal gradient of 30 C°/km with a zero intercept of 20° C. Cobanbarini Formation, Roper Group, Broadmere 1 well, depositional-erosional model 4.

APPENDIX N

ROCK-EVAL AND ORGANIC CARBON ANALYSES

Abbreviations:

S1 = free hydrocarbons released on heating to 300°C

S2 = hydrocarbons released on pyrolysis

S3 = carbon dioxide released on pyrolysis

Tmax = temperature of maximum release of hydrocarbons released on pyrolysis

PI = Production Index

HI = Hydrogen Index

OI = Oxygen Index

TOC = Total Organic Carbon

Full well and formation names are given in Appendices A and B

Note: Wells are organised in this appendix, alphabetically.

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/1

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: COBANBIRINI											
1145	152.5	436	.01	.02	0.00	.03	.	.33	0.00		
1146	180.4	346	.01	.02	0.00	.03	.	.33	0.00		
1147	193.3	437	.01	.16	0.00	.17	.	.06	0.00		
FORMATION: LANSEN CREEK SH											
1225	380.0	445	.17	.71	0.00	.88	.	.19	.80	89	0
1148	380.6	449	.20	.73	0.00	.93	.	.22	0.00		
1226	390.0	443	.23	.84	.42	1.07	2.00	.21	1.15	73	37
1149	393.5	461	.03	.23	0.00	.26	.	.12	0.00		
1227	400.0	443	.23	.74	.97	.97	.76	.24	1.80	41	54
1228	410.0	441	.20	.59	2.23	.79	.26	.25	1.49	40	150
1638	412.8	443	.34	1.00	.24	1.34	4.17	.25	1.49	67	16
1229	420.0	434	.22	.46	2.36	.68	.19	.32	.86	53	274
1639	424.0	438	.95	2.36	.43	3.31	5.49	.29	.90	262	48
1640	427.8	439	1.73	3.15	1.10	4.88	2.86	.35	.91	346	121
1230	430.0	442	.69	1.61	2.71	2.30	.59	.30	.93	173	291
1231	440.0	445	.45	1.30	2.57	1.75	.51	.26	1.14	114	225
1232	450.0	453	.04	.25	2.14	.29	.12	.14	0.00		
1233	460.0	462	.02	.18	.85	.20	.21	.10	0.00		
1234	470.0	266	.06	.14	.38	.20	.37	.30	0.00		
1235	480.0	452	.02	.14	.07	.16	2.00	.13	0.00		
1236	490.0	382	.05	.14	.06	.19	2.33	.26	0.00		
1237	500.0	453	.05	.21	.35	.26	.60	.19	0.00		
1238	510.0	445	.10	.30	0.00	.40	.	.25	0.00		
1239	520.0	444	.09	.43	.08	.52	5.38	.17	0.00		
1240	530.0	444	.08	.33	0.00	.41	.	.20	0.00		
1241	540.0	435	.22	.29	.24	.51	1.21	.43	0.00		
1242	550.0	433	.19	.36	.01	.55	36.00	.35	0.00		
1243	560.0	446	.07	.20	.20	.27	1.00	.26	0.00		
1150	560.7	445	.17	.53	0.00	.70	.	.24	0.00		
1244	569.0	445	.17	.39	.12	.56	3.25	.30	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/2

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MAINORU											
1151	7.7	327	0.00	.03	0.00	.03	.	0.00	0.00		
1152	37.9	332	0.00	.02	0.00	.02	.	0.00	0.00		
1153	66.3	276	.01	.01	0.00	.02	.	.50	0.00		
1154	84.5	338	0.00	0.00	0.00	0.00	.	.	0.00		
FORMATION: MANTUNGOLA											
2971	432.9	382	.01	.02	.14	.03	.14	.33	0.00		
2972	473.7	329	.02	.03	.01	.05	3.00	.40	0.00		
2973	490.9	347	.01	.03	0.00	.04	.	.25	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: ABNER SST											
3683	145.3	448	0.00	.11	0.00	.11	.	0.00	0.00		
3684	165.1	397	0.00	.03	0.00	.03	.	0.00	0.00		
FORMATION: MAINORU											
3685	400.7	401	0.00	.15	0.00	.15	.	0.00	0.00		
3686	459.2	303	0.00	.01	0.00	.01	.	0.00	0.00		
3687	459.9	262	0.00	0.00	0.00	0.00	.	.	0.00		
3688	467.4	277	0.00	.01	0.00	.01	.	0.00	0.00		
3689	473.0	357	0.00	.04	0.00	.04	.	0.00	0.00		
3690	478.5	467	.01	.14	0.00	.15	.	.07	0.00		
3691	478.7	404	0.00	.04	.28	.04	.14	0.00	0.00		
3692	504.9	430	0.00	.09	0.00	.09	.	0.00	0.00		
3693	528.8	327	0.00	.02	.11	.02	.18	0.00	0.00		
3694	542.2	277	0.00	0.00	.03	0.00	0.00	.	0.00		
3695	573.7	330	0.00	0.00	.13	0.00	0.00	.	0.00		
3696	582.9	271	0.00	0.00	.02	0.00	0.00	.	0.00		
3697	590.7	277	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/4

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: GALBARINI											
1155	54.3	259	0.00	0.00	0.00	0.00	.	.	0.00		
1156	61.6	389	0.00	.06	0.00	.06	.	0.00	0.00		
1157	61.8	309	0.00	.01	.93	.01	.01	0.00	0.00		
1158	84.2	307	0.00	0.00	.58	0.00	0.00	.	0.00		
1159	87.7	277	0.00	0.00	.11	0.00	0.00	.	0.00		
FORMATION: UNKNOWN											
1160	449.2	387	0.00	0.00	0.00	0.00	.	.	0.00		
1161	468.7	277	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/5

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-DON											
377	24.0	0	0.00	0.00	0.00	0.00	.	.	.05	0	0
378	31.4	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
379	33.3	0	0.00	0.00	0.00	0.00	.	.	.09	0	0
380	33.4	0	0.00	0.00	0.00	0.00	.	.	.17	0	0
381	38.6	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
1533	40.0	474	.15	.11	.22	.26	.50	.58	.76	14	29
382	40.2	0	0.00	0.00	0.00	0.00	.	.	.06	0	0
383	44.2	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
384	45.1	0	0.00	0.00	0.00	0.00	.	.	.06	0	0
FORMATION: LYNOTT-HS											
385	47.4	0	0.00	0.00	0.00	0.00	.	.	.21	0	0
386	51.3	0	0.00	0.00	0.00	0.00	.	.	.23	0	0
387	52.2	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
388	52.8	0	0.00	0.00	0.00	0.00	.	.	.22	0	0
389	54.3	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
1162	54.7	502	0.00	.43	.13	.43	3.31	0.00	.50	86	26
390	57.4	0	0.00	0.00	0.00	0.00	.	.	.08	0	0
391	58.0	0	0.00	0.00	0.00	0.00	.	.	.17	0	0
392	68.7	0	0.00	0.00	0.00	0.00	.	.	.44	0	0
393	73.3	0	0.00	0.00	0.00	0.00	.	.	.06	0	0
394	73.5	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
1534	74.1	416	.08	.10	.09	.18	1.11	.44	.50	20	18
395	75.0	0	0.00	0.00	0.00	0.00	.	.	.13	0	0
396	75.1	0	0.00	0.00	0.00	0.00	.	.	.09	0	0
397	75.2	0	0.00	0.00	0.00	0.00	.	.	.14	0	0
398	78.2	0	0.00	0.00	0.00	0.00	.	.	.39	0	0
399	80.8	0	0.00	0.00	0.00	0.00	.	.	.48	0	0
400	83.7	0	0.00	0.00	0.00	0.00	.	.	.22	0	0
401	83.8	0	0.00	0.00	0.00	0.00	.	.	.67	0	0
402	84.0	0	0.00	0.00	0.00	0.00	.	.	.33	0	0
403	89.6	0	0.00	0.00	0.00	0.00	.	.	.42	0	0
404	89.7	0	0.00	0.00	0.00	0.00	.	.	.36	0	0
405	95.7	0	0.00	0.00	0.00	0.00	.	.	.37	0	0
406	96.2	0	0.00	0.00	0.00	0.00	.	.	.30	0	0
1535	103.5	420	.07	.08	.03	.15	2.67	.47	.56	14	5
1163	104.7	551	0.00	.30	0.00	.30	.	0.00	.10	300	0
407	105.9	0	0.00	0.00	0.00	0.00	.	.	.36	0	0
408	110.6	0	0.00	0.00	0.00	0.00	.	.	.18	0	0
409	113.7	0	0.00	0.00	0.00	0.00	.	.	.16	0	0
410	113.9	0	0.00	0.00	0.00	0.00	.	.	.35	0	0
411	114.1	0	0.00	0.00	0.00	0.00	.	.	.49	0	0
412	114.3	0	0.00	0.00	0.00	0.00	.	.	.30	0	0
413	119.8	0	0.00	0.00	0.00	0.00	.	.	.27	0	0
414	120.5	0	0.00	0.00	0.00	0.00	.	.	.22	0	0
1164	120.7	508	.01	.14	.07	.15	2.00	.07	.13	108	54
415	126.2	0	0.00	0.00	0.00	0.00	.	.	.05	0	0
416	128.0	0	0.00	0.00	0.00	0.00	.	.	.04	0	0
417	129.5	0	0.00	0.00	0.00	0.00	.	.	.14	0	0
418	143.5	0	0.00	0.00	0.00	0.00	.	.	.36	0	0
419	151.2	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
420	155.4	0	0.00	0.00	0.00	0.00	.	.	.04	0	0
1536	156.6	403	.09	.07	0.00	.16	.	.56	.51	14	0
421	157.0	0	0.00	0.00	0.00	0.00	.	.	.33	0	0
422	163.6	0	0.00	0.00	0.00	0.00	.	.	.13	0	0
423	164.7	0	0.00	0.00	0.00	0.00	.	.	.08	0	0

1538	165.3	509	.11	.09	.14	.20	.64	.55	.69	13	20
424	165.5	0	0.00	0.00	0.00	0.00	.	.	1.46	0	0
1165	191.7	512	0.00	.28	.01	.28	28.00	0.00	.34	82	3
1539	316.2	427	.10	.04	0.00	.14	.	.71	.76	5	0
1166	324.9	508	.01	.28	.19	.29	1.47	.03	.16	175	119
1540	382.5	261	0.00	0.00	0.00	0.00	.	.	.55	0	0
1167	421.9	507	.02	.19	.11	.21	1.73	.10	.45	42	24
1543	452.2	470	.10	.04	.19	.14	.21	.71	1.21	3	16
1168	453.6	503	.02	.32	.13	.34	2.46	.06	1.18	27	11

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/6

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: STRETTON											
425	17.2	0	0.00	0.00	0.00	0.00	.	.	.05	0	0
FORMATION: YALCO											
1530	71.6	437	.09	3.03	.13	3.12	23.31	.03	.82	370	16
426	76.8	0	0.00	0.00	0.00	0.00	.	.	.08	0	0
427	86.6	0	0.00	0.00	0.00	0.00	.	.	.09	0	0
1531	88.0	427	.12	2.12	.06	2.24	35.33	.05	1.36	156	4
428	92.5	0	0.00	0.00	0.00	0.00	.	.	1.34	0	0
1532	94.1	439	.17	3.64	.24	3.81	15.17	.04	.84	433	29
1642	124.9	426	.03	.53	.05	.56	10.60	.05	0.00		
1549	125.5	429	.48	16.90	.30	17.38	56.33	.03	3.23	523	9
1169	125.7	434	1.49	31.55	.56	33.04	56.34	.05	5.37	588	10
429	126.6	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
1550	213.5	432	0.00	0.00	.35	0.00	0.00	.	0.00		
430	259.8	0	0.00	0.00	0.00	0.00	.	.	.04	0	0
431	266.8	0	0.00	0.00	0.00	0.00	.	.	.02	0	0
432	269.8	0	0.00	0.00	0.00	0.00	.	.	.08	0	0
433	271.4	0	0.00	0.00	0.00	0.00	.	.	.05	0	0
434	271.8	0	0.00	0.00	0.00	0.00	.	.	.05	0	0
FORMATION: LYNOTT-DON											
435	274.3	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
436	276.2	0	0.00	0.00	0.00	0.00	.	.	.13	0	0
437	281.5	0	0.00	0.00	0.00	0.00	.	.	.02	0	0
438	282.3	0	0.00	0.00	0.00	0.00	.	.	.02	0	0
439	282.4	0	0.00	0.00	0.00	0.00	.	.	.26	0	0
440	283.6	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
441	283.8	0	0.00	0.00	0.00	0.00	.	.	.04	0	0
442	287.4	0	0.00	0.00	0.00	0.00	.	.	.12	0	0
443	287.7	0	0.00	0.00	0.00	0.00	.	.	.10	0	0
444	288.5	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
445	290.0	0	0.00	0.00	0.00	0.00	.	.	.09	0	0
1643	290.3	440	.26	1.67	.22	1.93	7.59	.13	.56	298	39
1541	291.3	464	.07	.16	0.00	.23	.	.30	.81	20	0
446	294.3	0	0.00	0.00	0.00	0.00	.	.	.09	0	0
1170	295.0	528	.01	.10	1.44	.11	.07	.09	0.00		
447	297.9	0	0.00	0.00	0.00	0.00	.	.	.07	0	0
448	299.9	0	0.00	0.00	0.00	0.00	.	.	.05	0	0

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/7

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BALBARINI											
1171	31.1	437	0.00	0.00	0.00	0.00	.	.	0.00		
1542	54.2	437	.21	2.20	0.00	2.41	.	.09	.61	361	0
FORMATION: STRETTON											
1552	112.1	444	.03	.03	.22	.06	.14	.50	0.00		
FORMATION: YALCO											
1553	181.6	367	.24	0.00	.24	.24	0.00	1.00	0.00		
1172	186.3	440	.76	14.28	0.00	15.04	.	.05	3.99	358	0
1173	187.2	437	.45	8.77	3.40	9.22	2.58	.05	3.15	278	108
1174	193.2	450	.01	.44	5.22	.45	.08	.02	0.00		
1175	327.5	458	.04	.40	2.92	.44	.14	.09	0.00		
1176	382.8	441	0.00	0.00	2.23	0.00	0.00	.	0.00		
1177	391.5	234	0.00	0.00	.56	0.00	0.00	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: 82/8

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LANSEN CREEK SH											
1217	30.0	439	.09	1.98	0.00	2.07	.	.04	.99	200	0
1218	40.0	439	.03	.77	0.00	.80	.	.04	.58	133	0
1219	50.0	444	.01	.03	0.00	.04	.	.25	0.00		
1220	60.0	437	0.00	.06	.26	.06	.23	0.00	0.00		
1641	67.4	441	.02	.32	1.00	.34	.32	.06	.42	76	238
1221	70.0	441	.01	.47	0.00	.48	.	.02	.42	112	0
1222	80.0	441	0.00	.10	0.00	.10	.	0.00	0.00		
1223	90.0	441	.01	.68	0.00	.69	.	.01	.58	117	0
1224	100.0	452	0.00	.53	0.00	.53	.	0.00	.60	88	0

BASIN/AREA: MCARTHUR

WELL/LOCALITY: B8

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MCMINN											
3122	17.4	439	1.28	13.34	.25	14.62	53.36	.09	2.96	451	8
3123	22.6	440	.78	9.14	.23	9.92	39.74	.08	2.11	433	11
3348	22.8	440	.08	.99	.39	1.07	2.54	.07	.82	121	48
3349	25.4	421	.41	1.55	.22	1.96	7.05	.21	.30	517	73
3124	33.2	438	.36	4.49	.26	4.85	17.27	.07	1.83	245	14
3125	38.1	458	.02	.52	.23	.54	2.26	.04	.75	69	31
3350	40.0	464	.04	.37	.66	.41	.56	.10	.78	47	85
3351	43.4	468	0.00	.17	.48	.17	.35	0.00	.64	27	75
3126	50.9	466	.03	.03	.06	.06	.50	.50	0.00		
3127	59.4	436	.14	2.54	6.14	2.68	.41	.05	1.06	240	579
3128	64.0	436	.11	2.30	7.21	2.41	.32	.05	1.11	207	650
3129	68.6	440	.01	.02	.01	.03	2.00	.33	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BB2

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: REWARD DOLOMITE											
3039	72.0	451	.26	.34	.08	.60	4.25	.43	0.00		
353	72.9	432	.24	.33	.37	.57	.89	.42	.66	50	56
354	78.0	445	.52	.53	.47	1.05	1.13	.50	1.27	42	37
355	84.0	432	.56	.58	.49	1.14	1.18	.49	1.05	55	47
356	92.0	385	.24	.28	.33	.52	.85	.46	.63	44	52
358	104.1	444	.39	.43	.33	.82	1.30	.48	1.05	41	31
359	117.3	459	.32	.41	.21	.73	1.95	.44	1.53	27	14
360	126.3	450	.23	.36	.25	.59	1.44	.39	1.19	30	21
361	136.5	446	.20	.32	.24	.52	1.33	.38	1.20	27	20
362	138.8	456	.04	.10	.64	.14	.16	.29	.19	53	337
363	140.1	371	.09	.19	.13	.28	1.46	.32	.54	35	24
364	151.6	276	.03	.07	.23	.10	.30	.30	.14	50	164
365	153.2	338	.07	.13	.28	.20	.46	.35	.35	37	80
3040	163.5	475	.27	.27	.03	.54	9.00	.50	0.00		
FORMATION: BARNEY CREEK											
3041	273.3	481	.11	.18	0.00	.29	.	.38	0.00		
3042	374.0	500	.18	.66	0.00	.84	.	.21	3.32	20	0

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BB5

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: REWARD DOLOMITE											
3043	70.0	429	.18	.74	.16	.92	4.63	.20	1.49	50	11
3044	177.9	446	.28	.22	.16	.50	1.38	.56	0.00		
FORMATION: BARNEY CREEK											
3045	249.2	447	.24	.24	.07	.48	3.43	.50	0.00		
3046	314.1	445	.53	.69	.01	1.22	69.00	.43	1.67	41	1

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BC3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1731	292.0	431	.03	.08	.08	.11	1.00	.27	.74	11	11
1733	300.8	502	.03	.07	.08	.10	.88	.30	.85	8	9

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BJ1

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-CAR											
2974	18.2	453	.16	.17	.13	.33	1.31	.48	.48	35	27
2975	24.2	456	.53	1.17	.10	1.70	11.70	.31	2.47	47	4
FORMATION: BARNEY CREEK											
2976	30.6	454	.61	1.33	.48	1.94	2.77	.31	1.90	70	25

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BJ3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-CAR											
2977	26.5	458	2.08	3.53	1.15	5.61	3.07	.37	4.57	77	25
177	40.3	415	.19	.22	.81	.41	.27	.46	.29	76	279
179	44.6	444	.34	.64	.62	.98	1.03	.35	2.04	31	30
2978	45.9	464	.39	.58	.98	.97	.59	.40	1.54	38	64
180	49.4	435	.40	.50	1.18	.90	.42	.44	.83	60	142
184	51.7	416	.02	.06	.78	.08	.08	.25	.32	19	244
FORMATION: REWARD DOLOMITE											
186	55.3	418	.83	.52	.82	1.35	.63	.61	.56	93	146
187	55.9	425	.70	.91	.84	1.61	1.08	.43	1.05	87	80
188	56.6	417	1.21	.60	.79	1.81	.76	.67	.51	118	155
FORMATION: BARNEY CREEK											
190	60.0	455	.19	.34	.60	.53	.57	.36	.76	45	79
191	61.7	442	.23	.41	.41	.64	1.00	.36	2.08	20	20
2979	62.8	454	.48	1.50	.82	1.98	1.83	.24	2.89	52	28
192	64.0	451	.06	.14	.71	.20	.20	.30	.29	48	245
193	71.2	460	.01	.01	.56	.02	.02	.50	.03	33	1867
194	73.7	432	.23	.43	.61	.66	.70	.35	.44	98	139

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BJ6

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2980	171.1	442	.06	.06	.76	.12	.08	.50	0.00		
2981	194.0	398	.07	.08	.69	.15	.12	.47	.81	10	85

BASIN/AREA: MCARTHUR

WELL/LOCALITY: BROADMERE NO 1

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2	S3	S1+S2 per TONNE.....	S2/S3	PI	TOC %	HI	OI
FORMATION: LANSER CREEK SH											
2005	18.3	451	0.00	.11	.26	.11	.42	0.00	.28	39	93
2006	27.4	439	1.37	9.55	.32	10.92	29.84	.13	2.48	385	13
2007	36.6	438	1.66	12.15	.51	13.81	23.82	.12	2.98	408	17
2008	45.7	436	1.29	9.41	.70	10.70	13.44	.12	2.53	372	28
2009	54.9	436	3.32	12.69	.62	16.01	20.47	.21	3.05	416	20
2010	64.0	437	2.14	9.36	.69	11.50	13.57	.19	2.33	402	30
2011	73.2	438	1.89	9.41	.78	11.30	12.06	.17	2.45	384	32
2012	82.3	436	1.91	6.49	.80	8.40	8.11	.23	1.68	386	48
2013	91.4	436	2.25	7.35	.92	9.60	7.99	.23	2.03	362	45
2014	100.6	443	2.17	13.55	.80	15.72	16.94	.14	3.54	383	23
2015	109.7	441	2.09	15.58	.77	17.67	20.23	.12	4.30	362	18
2016	118.9	442	1.63	14.75	.74	16.38	19.93	.10	4.19	352	18
2017	128.0	437	1.54	12.12	.95	13.66	12.76	.11	3.79	320	25
2021	137.2	440	1.31	12.48	1.07	13.79	11.66	.09	4.18	299	26
2022	146.3	442	.96	9.25	1.11	10.21	8.33	.09	3.69	251	30
2018	155.4	442	1.22	10.17	1.04	11.39	9.78	.11	3.67	277	28
2023	164.6	445	.32	1.51	1.10	1.83	1.37	.17	.82	184	134
2026	173.7	453	.04	.31	.53	.35	.58	.11	.33	94	161
2029	182.9	453	.02	.09	.26	.11	.35	.18	.25	36	104
2023	192.0	451	.02	.06	.15	.08	.40	.25	.19	32	79
2035	201.2	411	.02	.09	.11	.11	.82	.18	.19	47	58
2038	210.3	369	.02	.04	.07	.06	.57	.33	.19	21	37
2040	216.4	349	.06	.04	.07	.10	.57	.60	.15	27	47
2043	225.6	316	.04	.04	.03	.08	1.33	.50	.16	25	19
2046	234.7	310	.04	.02	.06	.06	.33	.67	.15	13	40
2049	243.8	372	.07	.04	.09	.11	.44	.64	.17	24	53
2052	253.0	277	.07	0.00	.11	.07	0.00	1.00	.14	0	79
2055	262.1	327	.05	.01	.10	.06	.10	.83	.11	9	91
2058	271.3	269	.06	0.00	.05	.06	0.00	1.00	.12	0	42
2061	280.4	385	.36	.31	.64	.67	.48	.54	.26	119	246
2064	289.6	404	.25	.01	.27	.26	.04	.96	.17	6	159
2066	295.7	452	.11	.07	.25	.18	.28	.61	.19	37	132
2067	304.8	415	.37	.67	.35	1.04	1.91	.36	.41	163	85
2068	310.9	412	.22	.37	.54	.59	.69	.37	.28	132	193
2069	320.0	466	.22	.16	.16	.38	1.00	.58	.32	50	50
2070	329.2	463	.18	.28	.09	.46	3.11	.39	.38	74	24
2071	338.3	458	.93	6.31	.29	7.24	21.76	.13	3.44	183	8
2072	347.5	456	.62	2.39	.44	3.01	5.43	.21	1.45	165	30
2073	356.6	450	.46	.74	.24	1.20	3.08	.38	.51	145	47
2074	365.8	453	.29	.53	.19	.82	2.79	.35	.38	139	50
2075	374.9	460	.07	.21	0.00	.28	.	.25	.24	88	0
2076	384.0	462	.10	.14	.05	.24	2.80	.42	.13	108	38
2077	393.2	433	.05	.09	0.00	.14	.	.36	.13	69	0
2078	402.3	464	.13	.25	0.00	.38	.	.34	.27	93	0
2079	411.5	464	.39	.51	.04	.90	12.75	.43	.53	96	8
2080	420.6	465	.08	.17	.01	.25	17.00	.32	.14	121	7
2081	429.8	468	.13	.17	.01	.30	17.00	.43	.22	77	5
2082	438.9	468	.16	.14	.02	.30	7.00	.53	.21	67	10
2083	448.1	465	.27	.30	.02	.57	15.00	.47	.42	71	5
FORMATION: BESSIE CK SST											
2074	457.2	470	.18	.14	.01	.32	14.00	.56	.19	74	5
2085	466.3	452	.48	1.06	.11	1.54	9.64	.31	.71	149	15
2086	472.4	433	.40	.22	.10	.62	2.20	.65	.19	116	53
2087	481.6	414	.35	.11	.04	.46	2.75	.76	.16	69	25
2088	490.7	450	.25	.19	0.00	.44	.	.57	.20	95	0

2089	499.9	381	.11	.05	0.00	.16	.	.69	.13	38	0
2090	509.0	469	.11	.16	0.00	.27	.	.41	.22	73	0
2091	518.2	462	.31	.06	0.00	.37	.	.84	.14	43	0
2092	527.3	467	.26	.12	.02	.38	6.00	.68	.19	63	11
2093	536.4	450	.24	.15	.03	.39	5.00	.62	.21	71	14
2094	545.6	417	.17	.09	.01	.26	9.00	.65	.18	50	6
2095	554.7	451	.20	.13	0.00	.33	.	.61	.17	76	0
2096	563.9	457	.12	.11	0.00	.23	.	.52	.13	85	0
2097	573.0	399	.22	.10	.02	.32	5.00	.69	.15	67	13
2098	582.2	417	.10	.12	0.00	.22	.	.45	.14	86	0
2099	591.3	356	.09	.04	0.00	.13	.	.69	.10	40	0
2100	600.5	382	.19	.12	.01	.31	12.00	.61	.14	86	7
2101	609.6	357	.12	.03	0.00	.15	.	.80	.07	43	0
2102	618.7	317	.09	.02	0.00	.11	.	.82	.09	22	0
2103	627.9	270	.06	.01	0.00	.07	.	.86	.09	11	0
2104	637.0	319	.15	.04	0.00	.19	.	.79	.11	36	0
2105	646.2	242	.06	0.00	0.00	.06	.	1.00	.05	0	0
2106	655.3	249	.13	0.00	0.00	.13	.	1.00	.05	0	0
2107	664.5	228	.03	0.00	0.00	.03	.	1.00	.06	0	0
2108	673.6	228	.04	0.00	0.00	.04	.	1.00	.03	0	0
2109	682.8	228	.11	0.00	0.00	.11	.	1.00	.05	0	0
2110	691.9	228	.06	0.00	0.00	.06	.	1.00	.04	0	0
2111	701.0	228	.04	0.00	0.00	.04	.	1.00	.04	0	0
2112	710.2	269	.05	0.00	0.00	.05	.	1.00	.06	0	0
2113	719.3	437	.02	.02	0.00	.04	.	.50	.03	67	0
2114	728.5	354	.01	.02	0.00	.03	.	.33	.02	100	0
2115	737.6	277	.01	.02	0.00	.03	.	.33	.04	50	0
2116	746.8	277	.02	.02	0.00	.04	.	.50	.01	200	0
2117	755.9	277	.02	.02	0.00	.04	.	.50	.02	100	0
2118	765.0	216	.03	.02	0.00	.05	.	.60	.01	200	0
2119	774.2	216	.01	.02	0.00	.03	.	.33	0.00		
2120	783.3	216	.01	.01	0.00	.02	.	.50	.01	100	0
2121	792.5	237	.01	0.00	0.00	.01	.	1.00	.01	0	0
2122	801.6	210	.02	.03	0.00	.05	.	.40	0.00		
2123	810.8	210	.03	0.00	.01	.03	0.00	1.00	.01	0	100
FORMATION: CORCORAN											
2124	819.9	210	.01	0.00	0.00	.01	.	1.00	.03	0	0
2125	829.1	210	0.00	0.00	0.00	0.00	.	.	.06	0	0
2126	838.2	210	0.00	0.00	0.00	0.00	.	.	.08	0	0
2127	847.3	210	0.00	0.00	0.00	0.00	.	.	.07	0	0
2128	856.5	210	0.00	0.00	0.00	0.00	.	.	.08	0	0
2132	877.8	210	.02	0.00	0.00	.02	.	1.00	.16	0	0
2129	865.6	210	.01	0.00	0.00	.01	.	1.00	.05	0	0
2130	874.8	210	.01	0.00	0.00	.01	.	1.00	.07	0	0
2131	883.9	210	.01	0.00	0.00	.01	.	1.00	.08	0	0
2133	902.2	210	.03	0.00	0.00	.03	.	1.00	.12	0	0
2134	911.4	210	.03	0.00	0.00	.03	.	1.00	.10	0	0
2135	920.5	210	.08	0.00	0.00	.08	.	1.00	.10	0	0
2136	929.6	210	.02	0.00	0.00	.02	.	1.00	.04	0	0
2137	938.8	210	.01	0.00	0.00	.01	.	1.00	.02	0	0
2138	947.9	216	.02	0.00	0.00	.02	.	1.00	.03	0	0
2139	957.1	216	.03	.02	0.00	.05	.	.60	.02	100	0
2140	966.2	216	.01	.01	0.00	.02	.	.50	.01	100	0
FORMATION: DIORITE SILL											
2141	975.4	216	.01	.01	0.00	.02	.	.50	.01	100	0
2142	984.5	216	.01	.01	0.00	.02	.	.50	.03	33	0
2143	993.6	216	.03	.02	0.00	.05	.	.60	.01	200	0
2144	1002.8	216	.02	.01	0.00	.03	.	.67	.02	50	0
2145	1011.9	203	.09	0.00	0.00	.09	.	1.00	.01	0	0
2146	1021.1	216	.02	.01	0.00	.03	.	.67	.01	100	0
2147	1030.2	203	.02	0.00	0.00	.02	.	1.00	.03	0	0
2148	1039.4	216	.04	0.00	0.00	.04	.	1.00	.01	0	0

2149	1048.5	216	.06	0.00	0.00	.06	.	1.00	.01	0	0
2150	1057.7	216	.01	.01	0.00	.02	.	.50	.02	50	0
2151	1066.8	438	0.00	0.00	.03	0.00	0.00	.	.04	0	75
2152	1075.9	359	.01	0.00	.02	.01	0.00	1.00	.05	0	40
2153	1085.1	222	.01	0.00	.02	.01	0.00	1.00	.05	0	40
2154	1094.2	276	.01	0.00	0.00	.01	.	1.00	.05	0	0
2155	1103.4	258	.01	0.00	.01	.01	0.00	1.00	.04	0	25
2156	1112.5	222	.05	0.00	.02	.05	0.00	1.00	.06	0	33
2157	1121.7	276	.05	0.00	.02	.05	0.00	1.00	.06	0	33
2158	1130.8	259	.01	0.00	.04	.01	0.00	1.00	.03	0	133
2159	1140.0	248	.04	0.00	.07	.04	0.00	1.00	.04	0	175
FORMATION: CORCORAN											
2160	1149.1	246	.05	0.00	.02	.05	0.00	1.00	.04	0	50
2161	1158.2	250	.02	0.00	0.00	.02	.	1.00	.06	0	0
2162	1167.4	222	.02	0.00	0.00	.02	.	1.00	.05	0	0
2163	1176.5	276	.03	0.00	0.00	.03	.	1.00	.05	0	0
2164	1185.7	267	.03	0.00	0.00	.03	.	1.00	.05	0	0
2165	1194.8	251	.03	0.00	0.00	.03	.	1.00	.05	0	0
2166	1204.0	222	.09	0.00	0.00	.09	.	1.00	.07	0	0
2167	1213.1	303	.07	0.00	0.00	.07	.	1.00	.06	0	0
2168	1222.2	222	.10	0.00	0.00	.10	.	1.00	.08	0	0
2169	1231.4	276	.12	0.00	0.00	.12	.	1.00	.09	0	0
2170	1240.5	222	.05	0.00	0.00	.05	.	1.00	.06	0	0
2171	1249.7	276	.06	0.00	.05	.06	0.00	1.00	.07	0	71
2172	1258.8	222	.07	0.00	.01	.07	0.00	1.00	.10	0	10
2173	1268.0	334	.07	.02	.63	.09	.03	.78	.15	13	420
2174	1277.1	261	.11	0.00	.08	.11	0.00	1.00	.15	0	53
2175	1286.3	223	.07	0.00	.35	.07	0.00	1.00	.15	0	233
2176	1295.4	301	.07	0.00	.13	.07	0.00	1.00	.16	0	81
2177	1304.5	223	.04	0.00	.65	.04	0.00	1.00	.14	0	464
2178	1313.7	293	.04	0.00	.47	.04	0.00	1.00	.12	0	392
FORMATION: AGNER SST											
2179	1322.8	223	.06	0.00	0.00	.06	.	1.00	.05	0	0
2180	1332.0	293	.06	0.00	0.00	.06	.	1.00	.05	0	0
2181	1341.1	223	.07	0.00	.02	.07	0.00	1.00	.04	0	50
2182	1350.3	293	.02	0.00	0.00	.02	.	1.00	.04	0	0
2183	1359.4	223	.03	0.00	0.00	.03	.	1.00	.04	0	0
2184	1368.6	302	.04	0.00	0.00	.04	.	1.00	.04	0	0
2185	1377.7	223	.05	0.00	0.00	.05	.	1.00	.04	0	0
2186	1386.8	302	.06	0.00	0.00	.06	.	1.00	.07	0	0
2187	1396.0	223	.06	0.00	0.00	.06	.	1.00	.05	0	0
2188	1405.1	297	.07	0.00	0.00	.07	.	1.00	.04	0	0
2189	1414.3	223	.06	0.00	.02	.06	0.00	1.00	.03	0	67
2190	1423.4	280	.02	0.00	0.00	.02	.	1.00	.03	0	0
2191	1432.6	222	.04	0.00	0.00	.04	.	1.00	.03	0	0
2192	1441.7	280	.06	0.00	0.00	.06	.	1.00	.04	0	0
2193	1450.8	222	.07	0.00	.02	.07	0.00	1.00	.04	0	50
2194	1460.0	374	.37	.07	.10	.44	.70	.84	.09	78	111
2195	1469.1	434	.01	0.00	0.00	.01	.	1.00	.03	0	0
2196	1478.3	370	0.00	0.00	.01	0.00	0.00	.	.03	0	33
2197	1487.4	220	.01	0.00	0.00	.01	.	1.00	.03	0	0
2198	1496.6	288	.02	0.00	0.00	.02	.	1.00	.02	0	0
2199	1505.7	333	6.98	2.61	5.52	9.59	.47	.73	1.44	181	383
2200	1514.9	337	.10	.03	1.47	.13	.02	.77	.10	30	1470
2201	1524.0	264	0.00	0.00	0.00	0.00	.	.	.03	0	0
2202	1533.1	172	0.00	0.00	0.00	0.00	.	.	.03	0	0
2203	1542.3	257	.03	0.00	.12	.03	0.00	1.00	.05	0	240
2204	1551.4	248	.02	0.00	.02	.02	0.00	1.00	.04	0	50
2205	1560.6	184	.01	0.00	0.00	.01	.	1.00	.03	0	0
2206	1569.7	211	.01	0.00	.07	.01	0.00	1.00	.03	0	233
2207	1578.9	184	.01	0.00	.03	.01	0.00	1.00	.03	0	100
2208	1588.0	211	.03	.01	.01	.04	1.00	.75	.02	50	50

2209	1597.2	184	.03	0.00	.01	.03	0.00	1.00	.03	0	33
2210	1606.3	250	.06	.02	.65	.08	.03	.75	.27	7	241
2211	1615.4	255	.04	.02	.29	.06	.07	.67	.04	50	725
2212	1624.6	272	.01	0.00	0.00	.01	.	1.00	.03	0	0
2213	1633.7	255	.05	0.00	.01	.05	0.00	1.00	.06	0	17
2214	1642.9	251	.04	0.00	.01	.04	0.00	1.00	.03	0	33
2215	1652.0	238	.05	0.00	.01	.05	0.00	1.00	.03	0	33
2216	1661.2	238	.10	0.00	.03	.10	0.00	1.00	.05	0	60
2217	1670.3	238	.03	0.00	0.00	.03	.	1.00	.03	0	0
2218	1679.4	238	.04	0.00	0.00	.04	.	1.00	.05	0	0
2219	1688.6	238	.04	0.00	0.00	.04	.	1.00	.02	0	0
2220	1697.7	238	.10	0.00	.01	.10	0.00	1.00	.05	0	20
2221	1706.9	238	.04	0.00	0.00	.04	.	1.00	.03	0	0
2222	1716.0	268	.15	0.00	.03	.15	0.00	1.00	.04	0	75
2223	1725.2	264	.04	0.00	0.00	.04	.	1.00	.04	0	0
2224	1734.3	255	.03	0.00	0.00	.03	.	1.00	.03	0	0
2225	1743.5	270	.02	0.00	0.00	.02	.	1.00	.03	0	0
2226	1752.6	238	.04	0.00	.05	.04	0.00	1.00	.04	0	125
2227	1761.7	264	.07	0.00	.01	.07	0.00	1.00	.04	0	25
2228	1770.9	257	.06	0.00	0.00	.06	.	1.00	.03	0	0
2229	1780.0	255	.10	0.00	.02	.10	0.00	1.00	.05	0	40
2230	1792.2	379	.03	.02	.14	.05	.14	.60	.05	40	280
2231	1801.4	320	.10	.06	1.06	.16	.06	.63	.11	55	964
2232	1810.5	222	.04	0.00	.02	.04	0.00	1.00	.04	0	50
2233	1819.7	265	.02	0.00	.04	.02	0.00	1.00	.03	0	133
2234	1828.8	362	.03	.03	.22	.06	.14	.50	.04	75	550
2235	1837.9	336	.92	.51	1.83	1.43	.28	.64	.03	1700	6100
2236	1847.1	339	.04	0.00	.06	.04	0.00	1.00	.04	0	150
2237	1856.2	301	.01	0.00	0.00	.01	.	1.00	.03	0	0
2238	1865.4	425	.31	.23	.45	.54	.51	.57	.11	209	409
2239	1874.5	387	.09	.11	.15	.20	.73	.45	.07	157	214
2240	1880.6	261	.03	.01	0.00	.04	.	.75	.05	20	0
2241	1889.8	269	.04	.01	.19	.05	.05	.80	.03	33	633
2242	1898.9	247	.03	.01	.01	.04	1.00	.75	.03	33	33
2243	1908.0	242	0.00	0.00	0.00	0.00	.	.	.02	0	0
FORMATION: CRAWFORD											
2244	1917.2	276	.01	0.00	.36	.01	0.00	1.00	.04	0	900
2245	1926.3	261	.01	0.00	.04	.01	0.00	1.00	.03	0	133
2246	1935.5	242	.01	0.00	0.00	.01	.	1.00	.05	0	0
2247	1944.6	372	.09	.13	.08	.22	1.63	.41	.15	87	53
2248	1953.8	233	0.00	0.00	0.00	0.00	.	.	.06	0	0
2249	1962.9	267	.02	0.00	0.00	.02	.	1.00	.09	0	0
2250	1972.1	348	.06	.14	.12	.20	1.17	.30	.16	88	75
2251	1981.2	246	.01	0.00	0.00	.01	.	1.00	.10	0	0
2252	1990.3	343	.45	.59	1.49	1.04	.40	.43	.47	126	317
2253	1999.5	383	.23	.31	1.10	.54	.28	.43	.29	107	379
2254	2008.6	333	.79	.57	1.94	1.36	.29	.58	.52	110	373
2255	2017.8	339	.07	.01	.19	.08	.05	.88	.13	8	146
2256	2026.9	264	.18	.04	.29	.22	.14	.82	.15	27	193
2257	2036.1	222	.04	0.00	.05	.04	0.00	1.00	.15	0	33
2258	2045.2	176	.05	0.00	0.00	.05	.	1.00	.08	0	0
2259	2054.4	200	.07	0.00	.01	.07	0.00	1.00	.09	0	11
FORMATION: MAINORU											
2260	2063.5	182	.05	0.00	.05	.05	0.00	1.00	.12	0	42
2261	2072.6	217	.06	0.00	.02	.06	0.00	1.00	.12	0	17
2262	2081.8	333	1.72	1.39	2.53	3.11	.55	.55	.86	162	294
2263	2090.9	338	.07	.03	.21	.10	.14	.70	.24	13	88
2264	2100.1	307	.06	.03	.14	.09	.21	.67	.16	19	88
2265	2109.2	204	.05	0.00	.05	.05	0.00	1.00	.22	0	23
2266	2118.4	200	.16	0.00	.05	.16	0.00	1.00	.13	0	38
2267	2127.5	198	.44	0.00	.10	.44	0.00	1.00	.13	0	77
2268	2136.6	172	.87	0.00	.15	.87	0.00	1.00	.14	0	107

2269	2145.8	257	.31	0.00	.08	.31	0.00	1.00	.14	0	57
2270	2154.9	244	.15	0.00	.02	.15	0.00	1.00	.13	0	15
2271	2164.1	172	.58	0.00	.12	.58	0.00	1.00	.15	0	80
2272	2173.2	257	.25	0.00	.03	.25	0.00	1.00	.14	0	21

BASIN/AREA: MCARTHUR

WELL/LOCALITY: CA1

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: REWARD DOLOMITE											
1654	253.7	474	.17	.23	.11	.40	2.09	.43	1.29	18	9
1655	288.8	355	.10	.03	.16	.13	.19	.77	0.00		
1656	295.8	334	.07	.05	.07	.12	.71	.58	0.00		
FORMATION: BARNEY CREEK											
1657	337.6	539	.15	.67	.30	.82	2.23	.18	9.08	7	3
1658	390.0	331	0.00	.01	.16	.01	.06	0.00	0.00		
1659	573.1	297	0.00	0.00	0.00	0.00	.	.	0.00		
1660	787.3	275	0.00	.01	.14	.01	.07	0.00	0.00		
1661	889.3	412	0.00	.01	.25	.01	.04	0.00	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: CA2

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: REWARD DOLOMITE											
1662	261.5	431	0.00	.02	.11	.02	.18	0.00	0.00		
FORMATION: BARNEY CREEK											
1663	499.8	392	.06	.07	.08	.13	.88	.46	0.00		
1664	536.8	460	.03	.17	0.00	.20	.	.15	0.00		
1665	625.9	459	.10	.29	0.00	.39	.	.26	.53	55	0
FORMATION: TEENE DOLOMITE											
1666	654.9	454	.06	1.15	0.00	1.21	.	.05	2.14	54	0
1667	681.0	462	.40	.62	.10	1.02	6.20	.39	1.48	42	7
1668	687.2	454	.44	.66	.05	1.10	13.20	.40	1.67	40	3

BASIN/AREA: MCARTHUR

WELL/LOCALITY: CA3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT											
1669	181.9	460	.02	.05	0.00	.07	.	.29	0.00		
FORMATION: REWARD DOLOMITE											
1670	290.7	386	0.00	.02	.13	.02	.15	0.00	0.00		
FORMATION: BARNEY CREEK											
1671	425.2	275	.01	.03	0.00	.04	.	.25	0.00		
1672	481.4	335	.02	.02	0.00	.04	.	.50	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: F15/90

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1692	92.1	390	.07	.06	.68	.13	.09	.54	.59	10	115
1693	104.4	458	.07	.09	.48	.16	.19	.44	.62	15	77

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR1

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2810	17.8	439	.19	3.63	.15	3.82	24.20	.05	.92	395	16
2811	26.5	439	.82	10.30	.43	11.12	23.95	.07	1.69	609	25
2812	45.2	437	2.16	27.52	.70	29.68	39.31	.07	4.22	652	17
2813	50.8	438	.71	7.42	.60	8.13	12.37	.09	1.33	558	45
2814	92.2	439	1.48	17.25	.62	18.73	27.82	.08	2.92	591	21
2815	125.6	436	.88	5.80	.67	6.68	8.66	.13	1.38	420	49
2816	151.5	437	.78	7.41	.66	8.19	11.23	.10	1.68	441	39
2817	170.0	438	.16	.53	.55	.69	.96	.23	.35	151	157
2818	194.1	441	1.24	10.56	.65	11.80	16.25	.11	2.41	438	27
2819	223.4	428	.05	.12	.43	.17	.28	.29	0.00		
2820	256.5	438	.26	.90	.22	1.16	4.09	.22	.51	176	43
2821	279.5	437	.64	2.26	.34	2.90	6.65	.22	.94	240	36
2822	295.8	435	.36	1.16	.30	1.52	3.87	.24	.61	190	49
2823	320.2	437	.61	1.83	.28	2.44	6.54	.25	.88	208	32
2824	331.8	441	.44	.85	.24	1.29	3.54	.34	.64	133	38
2825	350.9	446	.02	0.00	.09	.02	0.00	1.00	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR2

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2826	45.5	437	.76	12.45	.34	13.21	36.62	.06	2.10	593	16
2827	62.9	437	4.90	66.39	1.15	71.29	57.73	.07	10.38	640	11
2828	86.1	438	1.35	16.74	.83	18.09	20.17	.07	2.61	641	32
2829	111.1	437	1.08	19.01	.81	20.09	23.47	.05	3.10	613	26
2830	147.0	439	1.26	17.52	.81	18.78	21.63	.07	3.06	573	26
2831	180.5	439	1.24	13.84	.87	15.08	15.91	.08	2.68	516	32
2832	202.2	434	1.04	8.28	.28	9.32	29.57	.11	2.00	414	14
2833	220.7	437	.48	3.01	.54	3.49	5.57	.14	.97	310	56
2834	238.2	439	.74	4.74	.66	5.48	7.18	.14	1.35	351	49

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2835	19.4	429	.37	3.23	.72	3.60	4.49	.10	.69	468	104
2836	30.1	433	1.41	18.58	.97	19.99	19.15	.07	2.82	659	34
2837	49.3	437	1.36	15.03	1.02	16.39	14.74	.08	2.34	642	44
2838	75.7	435	.21	2.30	.51	2.51	4.51	.08	.67	343	76
2839	79.8	435	.66	9.00	.57	9.66	15.79	.07	1.84	489	31
2840	106.7	436	1.73	18.82	.93	20.55	20.24	.08	3.22	584	29
2841	133.6	437	1.59	10.80	.98	12.39	11.02	.13	2.09	517	47
2842	162.8	436	.77	5.87	.84	6.64	6.99	.12	1.39	422	60
2843	194.5	431	.14	.67	.42	.81	1.60	.17	.41	163	102
2844	223.7	439	.34	1.60	.37	1.94	4.32	.18	.66	242	56
2845	250.6	436	.21	.88	.29	1.09	3.03	.19	.58	152	50
2846	274.6	438	.51	2.37	.38	2.88	6.24	.18	.95	249	40
2847	302.6	438	1.81	14.27	.94	16.08	15.18	.11	3.46	412	27
2848	311.8	433	.83	2.69	.27	3.52	9.96	.24	1.05	256	26
2849	373.9	437	.04	.02	.08	.06	.25	.67	0.00		
2850	399.9	403	.02	.02	.02	.04	1.00	.50	0.00		
FORMATION: COXCO DOLOMITE											
2851	486.0	274	.06	.04	.19	.10	.21	.60	0.00		
2852	505.0	308	.06	.05	.10	.11	.50	.55	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR4

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2853	107.7	437	.13	.85	.02	.98	42.50	.13	.51	167	4
2854	129.5	437	.24	2.05	.03	2.29	68.33	.10	.77	266	4
2855	151.4	435	.15	.99	.01	1.14	99.00	.13	.59	168	2
2856	162.6	449	.32	.96	.26	1.28	3.69	.25	.41	234	63
FORMATION: COXCO DOLOMITE											
2857	227.8	457	.01	.01	0.00	.02	.	.50	0.00		
2858	228.9	345	.01	0.00	0.00	.01	.	1.00	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR5

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2859	39.6	430	.12	1.37	.04	1.49	34.25	.08	.35	391	11
2860	54.0	433	.59	3.53	.39	4.12	9.05	.14	.73	484	53
2861	72.5	435	2.30	30.13	.79	32.43	38.14	.07	4.64	649	17
2862	95.9	438	1.46	12.52	.73	13.98	17.15	.10	2.31	542	32
2863	150.0	438	2.56	21.64	.88	24.20	24.59	.11	3.74	579	24
2864	177.9	439	1.06	6.83	.86	7.89	7.94	.13	1.53	446	56
2865	196.0	439	2.31	20.62	.94	22.93	21.94	.10	3.72	554	25
2866	213.9	434	3.39	24.83	1.03	28.22	24.11	.12	4.37	568	24
2867	257.4	442	.61	3.79	.64	4.40	5.92	.14	1.20	316	53
2868	281.0	434	.63	.91	.83	1.54	1.10	.41	.47	194	177
2869	306.3	439	.49	2.81	.55	3.30	5.11	.15	1.10	255	50
2870	324.4	430	.27	.65	.60	.92	1.08	.29	.44	148	136
2871	349.0	440	.37	1.11	.42	1.48	2.64	.25	.59	188	71
2872	377.1	438	.14	.22	.34	.36	.65	.39	0.00		
2873	400.8	437	.38	.99	.27	1.37	3.67	.28	.57	174	47
2874	426.0	438	.82	2.25	.35	3.07	6.43	.27	.98	230	36
2875	451.3	444	.58	1.30	.45	1.88	2.89	.31	.72	181	63
2876	470.6	444	.85	2.00	.39	2.85	5.13	.30	.95	211	41
2877	494.8	441	1.75	11.09	.50	12.84	22.18	.14	4.17	266	12
2878	512.3	445	.33	.88	.20	1.21	4.40	.27	.63	140	32

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR6

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: UNCERTAIN											
2879	33.1	438	.03	.09	0.00	.12	.	.25	0.00		
2880	40.8	325	.01	.01	0.00	.02	.	.50	0.00		
2881	74.2	436	.13	4.13	0.00	4.26	.	.03	1.46	283	0
2882	127.0	441	.01	.06	0.00	.07	.	.14	0.00		
2883	141.6	355	.01	0.00	.03	.01	0.00	1.00	0.00		
2884	149.0	229	0.00	0.00	0.00	0.00	.	.	0.00		
2885	176.3	241	.01	0.00	.02	.01	0.00	1.00	0.00		
2886	187.0	241	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR7

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2887	38.7	436	.53	6.72	.09	7.25	74.67	.07	1.15	584	8
2888	41.8	439	.40	4.08	.15	4.48	27.20	.09	.86	474	17
2889	50.3	439	3.07	36.38	.69	39.45	52.72	.08	4.97	732	14
2890	77.2	437	.92	13.65	.46	14.57	29.67	.06	2.26	604	20
2891	101.6	436	2.03	24.00	.72	26.03	33.33	.08	3.69	650	20
2892	116.0	438	4.68	40.76	.62	45.44	65.74	.10	5.67	719	11
2893	126.4	438	1.83	10.14	.59	11.97	17.19	.15	1.69	600	35
2894	151.1	438	2.85	26.49	.72	29.34	36.79	.10	3.87	684	19
2895	180.0	442	4.85	53.27	.70	58.12	76.10	.08	7.34	726	10
2896	209.6	440	1.27	15.07	.51	16.34	29.55	.08	2.34	644	22
2897	238.8	441	3.54	33.17	.73	36.71	45.44	.10	5.17	642	14
2898	252.9	441	2.51	22.70	.58	25.21	39.14	.10	3.50	649	17
2899	276.9	440	.68	3.96	.64	4.64	6.19	.15	1.09	363	59
2900	293.5	438	1.13	10.88	.74	12.01	14.70	.09	2.10	518	35
2901	351.8	440	.26	1.78	.41	2.04	4.34	.13	.76	234	54
2902	377.0	442	.38	1.92	.51	2.30	3.76	.17	.78	246	65
2903	400.9	444	.13	.42	.42	.55	1.00	.24	0.00		
2904	426.7	443	.36	1.50	.37	1.86	4.05	.19	.70	214	53
2905	458.0	440	.20	.43	.37	.63	1.16	.32	0.00		
2906	479.9	442	.45	1.44	.37	1.89	3.89	.24	.72	200	51
2907	510.1	442	.57	1.92	.48	2.49	4.00	.23	.90	213	53
2908	524.7	441	.25	.64	.33	.89	1.94	.28	.46	139	72
2909	554.0	443	.71	1.71	.40	2.42	4.28	.29	.84	204	48
2910	581.4	444	.74	1.89	.42	2.63	4.50	.28	.76	249	55
2911	601.5	445	1.08	2.90	.54	3.98	5.37	.27	1.25	232	43
2912	664.6	443	1.45	3.77	.42	5.22	8.98	.28	1.59	237	26
2913	699.9	440	.72	1.02	.27	1.74	3.78	.41	.59	173	46
2914	722.8	413	.65	.64	.39	1.29	1.64	.50	.30	213	130
2915	731.6	449	.99	2.85	.40	3.84	7.13	.26	1.44	198	28
2916	759.8	444	.94	1.49	.44	2.43	3.39	.39	.86	173	51
2917	794.6	448	1.08	2.51	.51	3.59	4.92	.30	1.54	163	33
1673	805.9	444	1.20	2.53	.36	3.73	7.03	.32	2.12	119	17
2918	840.8	446	.46	.71	.36	1.17	1.97	.39	.58	122	62
1674	854.0	451	1.29	4.83	.59	6.12	8.19	.21	3.67	132	16
1675	858.7	451	1.25	3.89	.74	5.14	5.26	.24	3.38	115	22
2919	866.5	446	1.71	4.48	.62	6.19	7.23	.28	2.81	159	22
1676	875.8	446	1.12	2.49	.76	3.61	3.28	.31	2.57	97	30
2921	894.6	449	.49	.54	.48	1.03	1.13	.48	.70	77	69
2922	903.0	450	.23	.38	.27	.61	1.41	.38	0.00		
1677	906.2	432	.01	.03	.30	.04	.10	.25	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR8

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2923	13.3	458	.06	.08	.15	.14	.53	.43	0.00		
2924	21.7	435	.60	7.85	.37	8.45	21.22	.07	1.63	482	23
2925	32.8	436	.30	5.19	.54	5.49	9.61	.05	1.19	436	45
2926	49.2	433	1.03	17.16	.93	18.19	18.45	.06	3.11	552	30
2927	63.7	435	.10	.99	.74	1.09	1.34	.09	.47	211	157
2928	99.0	425	.07	.15	.52	.22	.29	.32	0.00		
2929	109.1	438	.30	2.87	.38	3.17	7.55	.09	.88	326	43
2930	147.8	429	.08	.36	.44	.44	.82	.18	0.00		
2931	197.0	432	.20	.69	.41	.89	1.68	.22	.45	153	91
2932	226.4	437	.29	1.07	.38	1.36	2.82	.21	.54	198	70
2933	256.4	437	.39	1.69	.46	2.08	3.67	.19	.78	217	59
2934	273.0	434	.33	1.61	.49	1.94	3.29	.17	.77	209	64
2935	297.9	441	.39	1.97	.61	2.36	3.23	.17	.87	226	70
2936	326.0	439	.49	1.86	.72	2.35	2.58	.21	.90	207	80
2937	344.0	439	.50	2.22	.72	2.72	3.08	.18	.89	249	81
2938	349.3	440	.60	2.38	.77	2.98	3.09	.20	.97	245	79
2939	357.9	439	.49	1.77	.69	2.26	2.57	.22	.85	208	81
2940	368.0	440	.44	1.81	.62	2.25	2.92	.20	.94	193	66
2941	376.5	428	.15	.40	.11	.55	3.64	.27	0.00		
2942	403.4	443	.59	2.16	.23	2.75	9.39	.21	.99	218	23
2943	425.9	443	.60	2.12	.30	2.72	7.07	.22	1.00	212	30
2944	451.0	444	.79	2.36	.43	3.15	5.49	.25	1.13	209	38
2945	479.2	428	.09	.16	.27	.25	.59	.36	.13	123	208
2946	486.2	441	.59	1.40	.21	1.99	6.67	.30	.78	179	27
2947	503.1	443	.71	2.32	.25	3.03	9.28	.23	1.14	204	22
2948	519.3	446	.75	2.83	.28	3.58	10.11	.21	.53	534	53
2949	554.2	444	.79	1.64	.34	2.43	4.82	.33	.99	166	34
2950	570.8	444	1.24	7.36	.49	8.60	15.02	.14	4.18	176	12
2951	585.8	447	.51	1.11	.71	1.62	1.56	.31	.89	125	80

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR9

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
2952	47.0	436	.48	9.31	.54	9.79	17.24	.05	1.73	538	31
2953	55.7	435	.26	2.35	.62	2.61	3.79	.10	.71	331	87
2954	79.1	434	1.88	28.14	1.13	30.02	24.90	.06	4.27	659	26
2955	96.3	435	1.48	24.44	1.05	25.92	23.28	.06	3.91	625	27
2956	124.1	437	.79	11.81	1.03	12.60	11.47	.06	2.18	542	47
2957	151.1	432	1.78	25.05	1.28	26.83	19.57	.07	4.14	605	31
2958	175.9	438	.61	5.45	1.16	6.06	4.70	.10	1.29	422	90
2959	201.6	440	.23	1.86	.81	2.09	2.30	.11	0.00		
2960	209.0	431	.07	.18	.60	.25	.30	.28	0.00		
2961	227.0	434	.17	.85	.57	1.02	1.49	.17	.49	173	116
2962	251.0	431	.10	.42	.42	.52	1.00	.19	0.00		
2963	277.4	435	.19	.70	.40	.89	1.75	.21	.46	152	87
2964	303.0	439	0.00	0.00	.11	0.00	0.00		.52	0	21
2965	337.8	436	.34	2.02	.02	2.36		.14	.79	256	3
2966	357.9	434	.15	.61	.13	.76	4.69	.20	.41	149	32
2967	375.9	440	.18	.56	.16	.74	3.50	.24	.38	147	42
2968	401.0	441	.30	1.29	.10	1.59	12.90	.19	.63	205	16
1678	422.2	442	.24	1.69	.37	1.93	4.57	.12	1.54	110	24
2969	464.0	444	.43	1.75	.18	2.18	9.72	.20	.88	199	20
1679	468.7	445	.32	2.51	.40	2.83	6.28	.11	1.92	131	21
1680	469.6	443	.42	2.09	.30	2.51	6.97	.17	1.37	153	22
1681	485.5	447	0.00	.02	.35	.02	.06	0.00	0.00		
2970	494.3	435	.83	3.18	.37	4.01	8.59	.21	1.19	267	31
1682	500.1	444	.81	6.51	.45	7.32	14.47	.11	3.57	182	13

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR10

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
3444	23.2	433	.06	.68	0.00	.74	.	.08	.26	262	0
3445	37.4	439	.93	16.54	.03	17.47	.	.05	2.18	759	1
3049	51.9	437	.58	9.84	.34	10.42	28.94	.06	1.98	497	17
3446	57.9	438	.54	9.83	.16	10.37	61.44	.05	1.69	582	9
1808	80.1	435	1.83	17.82	.83	19.65	21.47	.09	2.48	719	33
1809	88.4	438	2.81	22.12	1.44	24.93	15.36	.11	3.00	737	48
3447	92.6	440	2.44	21.62	.93	24.06	23.25	.10	2.54	851	37
3448	104.2	439	1.06	8.34	1.00	9.40	8.34	.11	1.34	622	75
3449	133.8	440	1.93	13.29	1.27	15.22	10.46	.13	1.91	696	66
3450	137.3	442	2.88	9.90	1.34	12.78	7.39	.23	1.43	692	94
3451	141.9	443	2.31	40.40	1.19	42.71	33.95	.05	4.27	946	28
1810	143.3	440	2.75	36.85	1.83	39.60	20.14	.07	4.68	787	39
3452	146.4	443	1.42	3.91	1.29	5.33	3.03	.27	.70	559	184
3453	155.2	440	1.25	3.58	1.14	4.83	3.14	.26	.74	484	154
1811	170.3	438	.70	7.17	1.91	7.87	3.75	.09	1.30	552	147
1812	182.8	438	1.56	23.13	2.06	24.69	11.23	.06	2.95	784	70
3454	199.7	439	1.22	14.57	.75	15.79	19.43	.08	2.19	665	34
1813	232.8	438	2.70	30.10	2.27	32.80	13.26	.08	4.50	669	50
3455	236.9	440	1.80	16.97	1.11	18.77	15.29	.10	2.66	638	42
3456	242.9	440	1.32	4.67	1.32	5.99	3.54	.22	1.08	432	122
1814	252.1	438	2.53	27.78	2.46	30.31	11.29	.08	4.50	617	55
3457	286.1	426	.02	.13	.77	.15	.17	.13	.15	87	513
1815	291.0	433	1.28	3.09	2.45	4.37	1.26	.29	.73	423	336
1830	297.2	441	.69	3.07	2.24	3.76	1.37	.18	.90	341	249
3458	304.9	404	0.00	0.00	.25	0.00	0.00	.	1.40	0	18
1831	360.0	439	.12	.28	1.70	.40	.16	.30	.31	90	548
3459	397.4	230	0.00	0.00	.05	0.00	0.00	.	.52	0	10
1832	410.0	441	.24	.62	1.34	.86	.46	.28	.21	295	638
1833	443.0	444	.82	2.09	1.42	2.91	1.47	.28	.80	261	178
1834	469.8	444	.42	1.49	1.41	1.91	1.06	.22	.70	213	201
3460	478.2	442	.72	1.07	.39	1.79	2.74	.40	.44	243	89
1835	481.4	446	.75	2.62	1.36	3.37	1.93	.22	1.04	252	131
3461	499.0	436	.76	2.09	.32	2.85	6.53	.27	.66	317	48
3462	499.8	400	1.52	1.75	.83	3.27	2.11	.46	.39	449	213
3463	503.9	435	1.05	1.15	.59	2.20	1.95	.48	.46	250	128
1836	514.2	443	1.00	3.96	1.52	4.96	2.61	.20	1.46	271	104
1837	527.7	441	.37	.70	1.15	1.07	.61	.35	.52	135	221
3464	530.2	448	.70	3.31	.25	4.01	13.24	.17	1.21	274	21
1838	548.9	443	.63	.67	1.20	1.30	.56	.48	.49	137	245
1839	557.5	406	1.10	1.46	1.13	2.56	1.29	.43	.47	311	240
1840	559.9	454	.69	.52	.84	1.21	.62	.57	.48	108	175
1841	571.6	446	.77	2.50	.98	3.27	2.55	.24	1.22	205	80
1842	575.3	448	.69	2.33	.97	3.02	2.40	.23	1.24	188	78
1843	587.3	445	.74	1.34	1.03	2.08	1.30	.36	.83	161	124
1844	597.1	443	1.05	1.93	.33	2.98	5.85	.35	.96	201	34
1845	601.9	443	1.66	4.77	1.10	6.43	4.34	.26	2.45	195	45
1846	602.5	443	1.58	5.94	.98	7.52	6.06	.21	2.76	215	36
3465	603.9	448	1.55	7.81	.50	9.36	15.62	.17	3.27	239	15
1847	609.5	441	1.91	3.66	1.39	5.57	2.63	.34	1.72	213	81
1848	621.5	442	.71	.58	1.32	1.29	.44	.55	.95	61	139
1849	630.0	447	.68	.90	1.08	1.58	.83	.43	.69	130	157
1850	638.7	446	1.49	1.45	.95	2.94	1.53	.51	.48	302	198
1851	644.1	460	.14	.11	.96	.25	.11	.56	.22	50	436
1852	645.9	454	.92	1.78	1.57	2.70	1.13	.34	1.46	122	108
1853	646.9	459	.90	1.55	.95	2.45	1.63	.37	1.02	152	93
3466	650.4	448	1.55	8.48	.84	10.03	10.10	.15	3.21	264	26
1854	652.5	463	.27	.47	.54	.74	.87	.36	.37	127	146
1855	662.1	466	.82	2.03	.27	2.85	7.52	.29	.69	294	39
1856	668.5	470	0.00	.01	.09	.01	.11	0.00	.06	17	150

BASIN/AREA: MCARTHUR

WELL/LOCALITY: GR11

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1857	96.9	436	.20	1.25	0.00	1.45	.	.14	1.22	102	0
1858	118.3	429	.04	.18	0.00	.22	.	.18	.33	55	0
1859	132.0	433	.16	.50	0.00	.66	.	.24	.77	65	0
1860	178.9	438	.45	2.53	.03	2.98	84.33	.15	1.90	133	2
1861	202.8	435	.53	2.54	.32	3.07	7.94	.17	2.57	99	12
1862	204.4	430	.23	.91	.41	1.14	2.22	.20	1.32	69	31
1863	229.6	437	.35	1.49	.50	1.84	2.98	.19	1.61	93	31
1864	247.7	439	.59	2.81	.54	3.40	5.20	.17	2.09	134	26
1865	253.8	442	.60	3.27	.69	3.87	4.74	.16	2.15	152	32
3467	258.7	444	.51	3.13	.85	3.64	3.68	.14	1.16	270	73
1866	266.2	441	.38	1.64	.72	2.02	2.28	.19	1.61	102	45
1867	272.1	437	.50	2.24	.85	2.74	2.64	.18	2.14	105	40
1869	299.2	437	.20	.93	0.00	1.13	.	.18	1.09	85	0
1870	317.8	444	.45	1.62	.11	2.07	14.73	.22	1.66	98	7
1871	336.3	438	.28	1.36	0.00	1.64	.	.17	1.35	101	0
1872	339.4	446	.39	1.40	.16	1.79	8.75	.22	1.44	97	11
1873	347.3	443	.77	2.34	.31	3.11	7.55	.25	1.80	130	17
3468	347.4	445	.67	2.16	.71	2.83	3.04	.24	.98	220	72
1874	350.4	420	.28	1.11	.39	1.39	2.85	.20	.60	185	65
1875	378.3	443	.31	1.23	.08	1.54	15.38	.20	1.39	88	6
1876	382.1	446	.45	.91	.12	1.36	7.58	.33	1.48	61	8
1877	387.5	448	.59	2.21	.11	2.80	20.09	.21	1.80	123	6
1878	410.2	442	.88	2.46	.15	3.34	16.40	.26	2.71	91	6
1879	412.8	437	1.04	2.31	.49	3.35	4.71	.31	1.87	124	26
1880	415.2	446	1.12	6.41	.46	7.53	13.93	.15	5.38	119	9
3469	415.7	447	1.53	9.02	.71	10.55	12.70	.15	4.47	202	16
1881	422.2	434	.09	.11	.44	.20	.25	.45	.50	22	88
1882	424.3	446	.52	1.36	.33	1.88	4.12	.28	1.64	83	20
1883	426.1	436	.12	.18	.13	.30	1.38	.40	.45	40	29
1884	434.1	449	.61	1.17	.11	1.78	10.64	.34	0.00		
1885	437.2	449	.63	1.14	.12	1.77	9.50	.36	1.60	71	8
1886	438.2	447	.07	.11	0.00	.18	.	.39	.42	26	0
1887	441.9	452	.66	1.02	.05	1.68	20.40	.39	1.70	60	3
3470	442.0	447	.70	1.52	.94	2.22	1.62	.32	1.08	141	87
1888	443.2	455	.19	.33	0.00	.52	.	.37	1.13	29	0

BASIN/AREA: MCARTHUR

WELL/LOCALITY: KRATOS NO 11

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: CORCORAN											
1188	20.6	482	.01	.05	0.00	.06	.	.17	0.00		
1189	39.6	391	.02	.05	0.00	.07	.	.29	0.00		
1190	64.5	277	0.00	.03	0.00	.03	.	0.00	0.00		
1191	124.8	364	.01	.05	0.00	.06	.	.17	0.00		
1192	127.4	321	.01	.03	0.00	.04	.	.25	0.00		
1193	129.0	305	.01	.02	0.00	.03	.	.33	0.00		
1194	129.3	305	0.00	.01	0.00	.01	.	0.00	0.00		

1195	130.9	301	.01	.04	0.00	.05	.	.20	0.00
1196	132.0	277	0.00	.01	0.00	.01	.	0.00	0.00
1197	135.0	364	0.00	.02	0.00	.02	.	0.00	0.00
1198	136.9	320	.01	.02	0.00	.03	.	.33	0.00
1199	142.1	302	.01	.03	0.00	.04	.	.25	0.00
1200	164.7	273	0.00	0.00	0.00	0.00	.	.	0.00
1201	210.3	315	0.00	.03	0.00	.03	.	0.00	0.00
1202	246.9	277	0.00	.03	0.00	.03	.	0.00	0.00
1203	281.7	316	.01	.04	0.00	.05	.	.20	0.00
1204	322.8	347	0.00	0.00	0.00	0.00	.	.	0.00
1205	344.4	277	0.00	.04	0.00	.04	.	0.00	0.00
1206	370.0	298	0.00	0.00	2.83	0.00	0.00	.	0.00
1207	372.1	277	.01	.03	1.56	.04	.02	.25	0.00
1208	372.9	389	.01	.06	0.00	.07	.	.14	0.00
1209	384.0	357	0.00	.02	2.10	.02	.01	0.00	0.00
1210	389.8	336	0.00	.03	0.00	.03	.	0.00	0.00
1211	392.6	456	.01	.06	.11	.07	.55	.14	0.00

BASIN/AREA: MCARTHUR

WELL/LOCALITY: LEILA YARD NO 1

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-HS											
3020	21.4	511	.10	.15	.16	.25	.94	.40	0.00		
7	64.7	439	.07	.06	.33	.13	.18	.54	.10	60	330
8	65.9	337	.02	.03	.30	.05	.10	.40	.02	150	1500
9	66.7	277	.03	.09	.13	.12	.69	.25	.27	33	48
10	67.4	315	.03	.09	.12	.12	.75	.25	.45	20	27
13	84.9	224	.22	0.00	.32	.22	0.00	1.00	.07	0	457
17	90.0	277	.01	0.00	.23	.01	0.00	1.00	.24	0	96
18	90.4	277	.01	.09	0.00	.10	.	.10	.17	53	0
19	95.6	277	.03	.05	.27	.08	.19	.38	.03	167	900
23	101.6	256	.02	.02	.33	.04	.06	.50	.02	100	1650
27	113.7	225	.02	.02	.28	.04	.07	.50	0.00		
29	118.4	238	.04	.01	.45	.05	.02	.80	.07	14	643
30	118.9	349	.01	0.00	.23	.01	0.00	1.00	0.00		
31	119.3	293	.05	.08	.34	.13	.24	.38	.05	160	680
32	120.7	277	.03	.03	.49	.06	.06	.50	.30	10	163
33	121.2	292	.05	0.00	.27	.05	0.00	1.00	.95	0	28
34	121.5	230	0.00	0.00	.24	0.00	0.00	.	.05	0	480
35	121.7	230	.01	0.00	.34	.01	0.00	1.00	.03	0	1133
36	122.6	237	.02	.01	.29	.03	.03	.67	.04	25	725
37	123.3	216	.04	.03	.36	.07	.08	.57	.09	33	400
38	123.8	230	0.00	.01	.48	.01	.02	0.00	.05	20	960
39	124.0	277	.02	.06	.15	.08	.40	.25	.28	21	54
40	129.6	230	.01	.04	.39	.05	.10	.20	.13	31	300
41	129.8	277	.04	.17	.07	.21	2.43	.19	.94	18	7
43	134.5	230	.03	.03	.36	.06	.08	.50	.06	50	600
46	137.7	224	.02	.02	.30	.04	.07	.50	.05	40	600
47	148.2	230	0.00	.02	.31	.02	.06	0.00	.12	17	258
368	149.2	233	.02	.13	.21	.15	.62	.13	.16	81	131
3021	156.8	420	.09	.06	.13	.15	.46	.60	0.00		
57	168.6	430	.01	0.00	.08	.01	0.00	1.00	.23	0	35
70	188.0	337	.01	0.00	.10	.01	0.00	1.00	0.00		
72	191.6	390	.04	.08	0.00	.12	.	.33	1.07	7	0
73	192.1	279	.02	.01	.10	.03	.10	.67	.04	25	250
367	196.3	206	.02	.11	.32	.13	.34	.15	.11	100	291
77	196.4	359	.02	0.00	.12	.02	0.00	1.00	.07	0	171

79	198.4	279	.26	.06	.17	.32	.35	.81	.11	55	155
84	208.7	416	.02	.11	.08	.13	1.38	.15	.50	22	16
85	209.4	300	.03	.01	.04	.04	.25	.75	.07	14	57
86	209.8	279	.01	0.00	.03	.01	0.00	1.00	.03	0	100
87	210.9	407	.02	.01	.11	.03	.09	.67	.13	8	85
88	211.1	319	.03	.02	.03	.05	.67	.60	.13	15	23
89	211.5	279	.01	0.00	.13	.01	0.00	1.00	.08	0	163
90	212.1	359	.01	0.00	.17	.01	0.00	1.00	.08	0	213
91	212.9	327	.02	.04	.10	.06	.40	.33	.18	22	56
92	213.1	279	.04	.03	.08	.07	.38	.57	.17	18	47
93	213.7	331	.01	.05	0.00	.06	.	.17	.57	9	0
94	214.5	324	.02	.07	.05	.09	1.40	.22	.39	18	13
95	215.6	384	.04	.12	0.00	.16	.	.25	.71	17	0
100	226.9	279	0.00	0.00	.12	0.00	0.00	.	.11	0	109
102	230.5	351	.02	.01	.10	.03	.10	.67	.04	25	250
104	234.6	413	.01	.09	0.00	.10	.	.10	.76	12	0
366	236.5	231	.03	.10	.33	.13	.30	.23	.25	40	132
105	236.6	279	0.00	0.00	.02	0.00	0.00	.	.10	0	20
106	239.4	416	0.00	.03	0.00	.03	.	0.00	.27	11	0
108	244.7	492	.02	.12	.04	.14	3.00	.14	.40	30	10
109	246.4	279	.01	0.00	.18	.01	0.00	1.00	.04	0	450
112	253.9	416	.03	.01	.10	.04	.10	.75	.09	11	111
369	263.7	225	.03	.14	.25	.17	.56	.18	.33	42	76
FORMATION: LYNOTT-CAR											
119	270.7	432	0.00	.02	0.00	.02	.	0.00	.30	7	0
3022	271.4	323	.04	.02	0.00	.06	.	.67	0.00		
120	272.5	279	0.00	0.00	0.00	0.00	.	.	.08	0	0
124	274.1	416	.02	.02	0.00	.04	.	.50	.35	6	0
125	276.4	407	.02	.05	.04	.07	1.25	.29	.62	8	6
126	277.4	279	.02	0.00	.03	.02	0.00	1.00	.12	0	25
128	282.0	416	.01	0.00	.06	.01	0.00	1.00	.25	0	24
129	283.2	403	.02	.03	.09	.05	.33	.40	.25	12	36
136	286.6	306	.05	.03	0.00	.08	.	.63	.25	12	0
140	298.1	279	.02	0.00	0.00	.02	.	1.00	.05	0	0
141	299.5	328	.01	0.00	0.00	.01	.	1.00	.08	0	0
370	305.3	225	.01	.08	.02	.09	4.00	.11	.16	50	13
372	307.5	244	.17	.19	.40	.36	.48	.47	1.26	15	32
143	312.3	318	.02	.02	0.00	.04	.	.50	.45	4	0
146	316.6	279	0.00	0.00	0.00	0.00	.	.	.34	0	0
147	317.3	428	0.00	0.00	.07	0.00	0.00	.	.17	0	41
371	318.3	214	.02	.10	.08	.12	1.25	.17	.08	125	100
149	319.9	218	0.00	0.00	.07	0.00	0.00	.	.21	0	33
150	321.4	279	0.00	.02	.07	.02	.29	0.00	.08	25	88
155	327.1	279	.03	.09	.04	.12	2.25	.25	1.74	5	2
158	332.5	244	0.00	0.00	.46	0.00	0.00	.	.06	0	767
159	335.6	245	.02	.04	.19	.06	.21	.33	.51	8	37
162	338.5	248	0.00	0.00	.13	0.00	0.00	.	.51	0	25
163	341.6	311	.01	.02	.11	.03	.18	.33	1.26	2	9
164	344.1	342	.01	.03	.18	.04	.17	.25	1.15	3	16
165	351.7	304	.01	.02	.14	.03	.14	.33	1.14	2	12
166	355.2	299	.01	.03	.22	.04	.14	.25	1.16	3	19
168	358.3	341	0.00	.05	.17	.05	.29	0.00	1.36	4	13
169	359.2	345	.01	.05	.21	.06	.24	.17	1.78	3	12
170	359.5	327	.02	.04	.53	.06	.08	.33	1.73	2	31
171	359.8	324	.01	.03	.62	.04	.05	.25	1.53	2	41
172	363.6	279	0.00	.01	.75	.01	.01	0.00	1.15	1	65
373	381.3	302	.03	.18	.27	.21	.67	.14	.56	32	48
376	397.5	357	.03	.17	.37	.20	.46	.15	.14	121	264
374	507.5	289	.04	.17	.13	.21	1.31	.19	1.10	15	12
375	545.1	250	.02	.10	.27	.12	.37	.17	.53	19	51

BASIN/AREA: MCARTHUR

WELL/LOCALITY: M2

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1697	125.4	444	.35	.42	1.19	.77	.35	.45	.97	43	123
1699	130.3	436	.64	.72	.66	1.36	1.09	.47	1.19	61	55
1744	339.9	470	.19	.24	.10	.43	2.40	.44	.91	26	11
1746	355.2	460	.18	.19	.10	.37	1.90	.49	.95	20	11

BASIN/AREA: MCARTHUR

WELL/LOCALITY: M3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1701	145.1	450	.47	3.00	.51	3.47	5.88	.14	2.11	142	24
1707	178.7	456	.23	.72	.40	.95	1.80	.24	.92	78	43
1740	334.6	464	.13	.11	.13	.24	.85	.54	.65	17	20

BASIN/AREA: MCARTHUR

WELL/LOCALITY: M13

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MCMINN											
3143	20.7	442	0.00	.62	.06	.62	10.33	0.00	.97	64	6
3144	27.4	438	.03	.82	.08	.85	10.25	.04	.62	132	13
3145	35.7	436	.05	1.64	.16	1.69	10.25	.03	1.16	141	14
3146	55.2	440	.04	3.21	.19	3.25	16.89	.01	1.51	213	13
3147	68.6	438	.06	3.73	.59	3.79	6.32	.02	1.62	230	36
3148	77.1	436	.04	3.10	.24	3.14	12.92	.01	1.57	197	15
3149	78.9	441	.02	1.39	.10	1.41	13.90	.01	1.53	91	7
3150	86.6	443	.01	.16	.04	.17	4.00	.06	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: M17/08

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1695	111.9	456	.15	.23	.71	.38	.32	.39	1.41	16	50
1698	126.6	457	.23	.62	.81	.85	.77	.27	3.20	19	25
1702	147.8	453	.22	.49	.37	.71	1.32	.31	2.97	16	12
1706	173.5	397	.19	.09	.43	.28	.21	.68	1.00	9	43
1711	193.9	350	.09	.06	.22	.15	.27	.60	.89	7	25
1714	242.0	322	.01	.04	.04	.05	1.00	.20	.62	6	6
1716	262.6	320	.02	.05	.10	.07	.50	.29	.70	7	14
1717	269.8	537	.02	.36	.19	.38	1.89	.05	.55	65	35
1720	278.6	547	.02	.19	.14	.21	1.36	.10	.61	31	23
1721	279.7	446	.01	.04	.42	.05	.10	.20	.35	11	120
1723	282.1	551	.02	.36	.15	.38	2.40	.05	.66	55	23
1725	288.4	549	.02	.14	.13	.16	1.08	.13	.57	25	23
1732	300.3	552	.02	.12	.09	.14	1.33	.14	.60	20	15
1735	311.5	550	.02	.88	.08	.90	11.00	.02	.64	138	13
1741	320.6	548	.02	.36	0.00	.38	.	.05	.70	51	0
1738	326.9	548	.02	.33	.32	.35	1.03	.06	.61	54	52
1743	339.5	540	.02	.26	.14	.28	1.86	.07	.56	46	25
1745	351.4	394	0.00	.03	.10	.03	.30	0.00	.30	10	33

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MARINER NO D1

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MAINORU											
1183	23.4	313	0.00	0.00	0.00	0.00	.	.	0.00		
1184	42.0	245	0.00	0.00	0.00	0.00	.	.	0.00		
1185	85.0	304	0.00	0.00	0.00	0.00	.	.	0.00		
1186	102.9	243	0.00	0.00	0.00	0.00	.	.	0.00		
1187	142.2	335	0.00	.03	0.00	.03	.	0.00	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MANT 78-1

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-CAR											
196	208.7	498	.07	.19	.42	.26	.45	.27	.78	24	54
197	212.2	394	.09	.11	.46	.20	.24	.45	.28	39	164
198	213.8	390	.04	.07	.34	.11	.21	.36	.51	14	67
199	214.6	441	.06	.18	.74	.24	.24	.25	.56	32	132
200	220.5	503	.08	.23	.32	.31	.72	.26	.90	26	36
201	222.9	472	.17	.21	.37	.38	.57	.45	1.51	14	25
203	229.5	442	.07	.08	.41	.15	.20	.47	.38	21	108
208	244.9	348	.07	.05	.35	.12	.14	.58	.83	6	42
211	247.6	448	.12	.14	.21	.26	.67	.46	1.48	9	14
212	249.6	504	.08	.15	.40	.23	.38	.35	.93	16	43
219	266.0	340	.05	.02	.45	.07	.04	.71	.16	13	281
220	267.8	398	.09	.09	.46	.18	.20	.50	.35	26	131
222	269.6	365	.07	.07	.39	.14	.18	.50	.69	10	57
226	275.3	504	.07	.17	.27	.24	.63	.29	1.07	16	25
229	286.6	430	0.00	0.00	.23	0.00	0.00		.07	0	329
233	294.6	358	.01	.02	.29	.03	.07	.33	.11	18	264
239	336.1	390	.02	.09	.23	.11	.39	.18	.99	9	23
241	343.0	307	.02	.02	.30	.04	.07	.50	.11	18	273
243	349.6	353	.08	.13	.27	.21	.48	.38	1.06	12	25
244	351.1	348	.09	.14	.22	.23	.64	.39	.88	16	25
245	351.4	441	.09	.23	.29	.32	.79	.28	3.44	7	8
246	354.0	337	.03	.08	.60	.11	.13	.27	1.07	7	56
250	361.4	278	0.00	.02	.30	.02	.07	0.00	.14	14	214
251	364.5	415	.11	.21	.49	.32	.43	.34	1.23	17	40
253	378.9	340	.05	.08	.44	.13	.18	.38	.34	24	129
254	381.3	278	.03	.10	.41	.13	.24	.23	.67	15	61
255	397.5	304	.05	.11	.25	.16	.44	.31	.54	20	46
258	411.9	271	.03	.12	.25	.15	.48	.20	.74	16	34
259	412.3	271	.03	.17	.21	.20	.81	.15	1.43	12	15
260	415.5	245	.04	.11	.29	.15	.38	.27	.49	22	59
261	417.2	297	.03	.19	.20	.22	.95	.14	1.38	14	14
263	419.5	245	.05	.06	.29	.11	.21	.45	.30	20	97
264	421.5	254	.06	.08	.23	.14	.35	.43	.29	28	79
267	427.1	254	.02	.08	.16	.10	.50	.20	.29	28	55
268	430.2	245	.04	.07	.32	.11	.22	.36	.27	26	119
270	440.9	245	.03	.09	.28	.12	.32	.25	.28	32	100
271	442.2	271	.03	.13	.31	.16	.42	.19	.79	16	39
272	443.5	264	.03	.10	.52	.13	.19	.23	.07	143	743
273	445.0	290	.02	.11	.33	.13	.33	.15	.77	14	43
274	454.0	271	.03	.14	.33	.17	.42	.18	.11	127	300
276	466.0	245	.01	.09	.31	.10	.29	.10	.13	69	238
278	470.1	271	.03	.18	.23	.21	.78	.14	1.56	12	15
279	478.5	254	.03	.14	.37	.17	.38	.18	1.57	9	24
281	484.4	483	.03	.27	.39	.30	.69	.10	2.34	12	17
285	504.1	277	.01	.05	.61	.06	.08	.17	.28	18	218
286	505.4	351	.02	.17	.33	.19	.52	.11	.58	29	57
287	507.5	277	.01	.05	.45	.06	.11	.17	.58	9	78
288	518.1	360	.01	.03	.39	.04	.08	.25	.23	13	170
289	536.1	277	.01	.02	.50	.03	.04	.33	.18	11	278
293	545.1	342	.02	.04	.45	.06	.09	.33	.60	7	75
294	554.0	318	.02	.07	.40	.09	.18	.22	1.11	6	36
297	560.1	317	.01	.07	.32	.08	.22	.13	1.63	4	20
299	565.0	277	.02	.04	.48	.06	.08	.33	1.22	3	39
300	568.8	374	.02	.10	.41	.12	.24	.17	1.39	7	29
303	571.1	344	.03	.10	.52	.13	.19	.23	1.71	6	30

305	579.5	278	.01	.02	.76	.03	.03	.33	.32	6	238
306	584.2	396	.01	.15	.37	.16	.41	.06	2.36	6	16
308	590.8	467	.02	.10	.07	.12	1.43	.17	1.57	6	4
309	602.0	276	.02	.10	.28	.12	.36	.17	.88	11	32
FORMATION: REWARD DOLOMITE											
310	606.3	287	0.00	.01	.21	.01	.05	0.00	.10	10	210
313	614.9	276	.03	.07	.25	.10	.28	.30	.56	13	45
315	621.7	311	.02	.03	.43	.05	.07	.40	.26	12	165
316	625.2	276	.19	.03	.41	.22	.07	.86	.08	38	513

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MANT 79-3

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: LYNOTT-CAR											
3009	24.2	467	.23	.27	.41	.50	.66	.46	1.63	17	25
320	45.3	291	.22	.21	.32	.43	.66	.51	.51	41	63
321	46.5	353	.24	.20	.23	.44	.87	.55	1.12	18	21
323	57.3	468	.18	.31	.24	.49	1.29	.37	2.06	15	12
325	75.2	443	.10	.15	.38	.25	.39	.40	1.01	15	38
326	77.9	314	.06	.11	.31	.17	.35	.35	.44	25	70
329	99.0	300	.10	.16	.29	.26	.55	.38	.70	23	41
331	107.2	276	.02	.05	.28	.07	.18	.29	.20	25	140
332	113.8	305	.03	.13	.14	.16	.93	.19	1.62	8	9
333	117.7	347	.04	.08	.36	.12	.22	.33	1.14	7	32
335	127.1	349	.03	.10	.35	.13	.29	.23	1.64	6	21
336	127.8	326	.05	.15	.41	.20	.37	.25	1.43	10	29
337	128.4	241	.06	.18	.27	.24	.67	.25	1.13	16	24
338	130.6	276	.04	.07	.53	.11	.13	.36	.39	18	136
339	134.2	318	.03	.09	.48	.12	.19	.25	.26	35	185
340	142.6	296	.14	.25	.42	.39	.60	.36	1.90	13	22
341	144.2	331	.04	.17	.34	.21	.50	.19	2.02	8	17
343	147.9	276	.02	.07	.51	.09	.14	.22	.42	17	121
3010	151.2	469	.07	.14	.16	.21	.88	.33	0.00		
344	156.7	341	.05	.19	.30	.24	.63	.21	.97	20	31
FORMATION: REWARD DOLOMITE											
345	164.6	276	.03	.05	.36	.08	.14	.38	.17	29	212
347	172.3	321	.04	.08	.41	.12	.20	.33	.38	21	108
348	174.3	276	.03	.09	.33	.12	.27	.25	.15	60	220
349	177.0	276	.02	.02	.35	.04	.06	.50	.10	20	350
3011	279.8	449	.05	.11	.24	.16	.46	.31	1.07	10	22
3012	349.8	427	.08	.11	.25	.19	.44	.42	1.82	6	14

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MCA5

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
3025	59.4	446	.36	.92	.09	1.28	10.22	.28	.99	93	9
3026	74.0	449	.72	1.39	.14	2.11	9.93	.34	1.72	81	8
3027	138.2	441	.10	.14	.05	.24	2.80	.42	0.00		
3028	206.0	444	.15	.11	.03	.26	3.67	.58	0.00		
3029	265.0	428	.79	.61	.06	1.40	10.17	.56	.98	62	6
3030	306.4	438	.54	.50	.07	1.04	7.14	.52	1.22	41	6
3031	357.4	463	.46	.36	0.00	.82	.	.56	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MCA10

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
3032	27.8	458	.47	1.13	.05	1.60	22.60	.29	4.05	28	1
3033	36.6	445	.17	.15	.03	.32	5.00	.53	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MCARTHUR NO 6

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: UNNAM BAS RP											
1178	199.0	308	0.00	0.00	.02	0.00	0.00	.	0.00		
1179	234.4	234	0.00	0.00	0.00	0.00	.	.	0.00		
1180	246.8	307	0.00	0.00	0.00	0.00	.	.	0.00		
1181	247.1	234	0.00	0.00	0.00	0.00	.	.	0.00		
1182	260.1	307	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MY4

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
3013	20.4	437	.22	1.43	.11	1.65	13.00	.13	1.21	118	9
3014	56.1	440	.56	2.56	.30	3.12	8.53	.18	1.79	143	17
3015	79.4	445	.40	1.46	.39	1.86	3.74	.22	1.33	110	29

BASIN/AREA: MCARTHUR

WELL/LOCALITY: MY5

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: REWARD DOLOMITE											
3016	66.9	442	.21	1.23	.95	1.44	1.29	.15	.63	195	151
3017	67.2	441	.89	10.50	1.07	11.39	9.81	.08	3.65	288	29
FORMATION: BARNEY CREEK											
3018	288.0	446	.33	.54	.59	.87	.92	.38	.74	73	80
3019	330.7	436	.31	.42	.26	.73	1.62	.42	.69	61	38

BASIN/AREA: MCARTHUR

WELL/LOCALITY: N27/63

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1690	31.8	452	.19	.13	.26	.32	.50	.59	.78	17	33
1694	105.5	465	.11	.32	.54	.43	.59	.26	1.98	16	27
1696	116.4	468	.03	.05	.70	.08	.07	.38	.56	9	125
1700	145.3	445	.04	.04	.06	.08	.67	.50	1.18	3	5
1703	153.0	422	0.00	0.00	.21	0.00	0.00	.	.71	0	30
1704	158.7	373	.07	.07	.35	.14	.20	.50	.99	7	35
1705	172.8	455	.28	.47	.42	.75	1.12	.37	2.75	17	15
1708	188.4	400	.02	.02	.28	.04	.07	.50	.48	4	58
1710	193.2	433	.03	.07	.17	.10	.41	.30	.75	9	23
1713	223.2	430	.04	.09	.27	.13	.33	.31	.88	10	31
1715	244.2	303	.03	.05	.29	.08	.17	.38	.38	13	76
1718	276.0	431	.02	.08	.11	.10	.73	.20	.71	11	15
1719	278.2	551	.01	.17	.04	.18	4.25	.06	.95	18	4
1724	289.6	550	.05	.98	.08	1.03	12.25	.05	.79	124	10
1734	308.4	536	.05	.27	.07	.32	3.86	.16	.58	47	12
1736	313.0	550	.02	.53	.03	.55	17.67	.04	.51	104	6
1737	315.3	551	.02	.35	.04	.37	8.75	.05	.53	66	8
1739	329.4	550	.01	.37	.07	.38	5.29	.03	.58	64	12
1742	335.1	548	.01	.49	0.00	.50	.	.02	.68	72	0
1747	355.6	534	.02	.31	.03	.33	10.33	.06	.47	66	6
1749	381.0	540	0.00	.03	0.00	.03	.	0.00	.34	9	0
1750	388.9	438	.01	.04	.27	.05	.15	.20	.25	16	108

BASIN/AREA: MCARTHUR

WELL/LOCALITY: S15/31

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1691	87.0	461	.03	.01	.22	.04	.05	.75	.33	3	67

BASIN/AREA: MCARTHUR

WELL/LOCALITY: T19

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MCMINN											
3151	17.8	437	.12	3.01	3.79	3.13	.79	.04	1.38	218	275
3152	21.7	436	.19	4.95	3.06	5.14	1.62	.04	1.37	361	223
3153	30.2	436	.15	3.29	3.85	3.44	.85	.04	1.60	206	241
3154	34.4	436	.09	3.40	4.93	3.49	.69	.03	1.47	231	335
3155	40.5	439	.04	4.80	.20	4.84	24.00	.01	1.08	444	19
3156	48.2	435	.01	.28	.12	.29	2.33	.03	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: URAPUNGA NO 1

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MAINORU											
1322	14.4	471	0.00	0.00	.08	0.00	0.00	.	0.00		
1323	19.2	276	0.00	.01	0.00	.01	.	0.00	0.00		
1324	27.2	276	.01	0.00	0.00	.01	.	1.00	0.00		
1325	47.4	264	0.00	0.00	0.00	0.00	.	.	0.00		
1326	61.1	309	0.00	.01	.14	.01	.07	0.00	0.00		
1327	66.0	273	0.00	0.00	0.00	0.00	.	.	0.00		
1328	75.2	276	.01	.01	0.00	.02	.	.50	0.00		
1329	102.9	302	0.00	.01	0.00	.01	.	0.00	0.00		
1330	107.5	307	.01	.04	0.00	.05	.	.20	0.00		
1331	114.4	276	.01	.01	0.00	.02	.	.50	0.00		
1332	120.9	334	0.00	.01	0.00	.01	.	0.00	0.00		
1333	221.3	262	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: URAPUNGA NO 2

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: CORCORAN											
1334	6.4	245	0.00	0.00	0.00	0.00	.	.	0.00		
1335	27.6	269	0.00	0.00	0.00	0.00	.	.	0.00		
1336	48.9	245	0.00	0.00	0.00	0.00	.	.	0.00		
1337	67.3	276	0.00	0.00	0.00	0.00	.	.	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: URAPUNGA NO 3

ID	DEPTH M	TMAX DEG C	S1 .....KG	S2 per	S3 TONNE.....	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: VELKERRI											
1363	30.0	439	3.05	4.74	.33	7.79	14.36	.39	.74	641	45
1522	39.9	441	3.03	30.20	.17	33.23	.	.09	7.20	419	2
1364	40.0	444	2.99	30.33	.54	33.32	56.17	.09	6.09	498	9
1365	45.0	443	2.68	26.54	.51	29.22	52.04	.09	5.63	471	9
1366	50.0	445	3.06	22.84	.63	25.90	36.25	.12	5.78	395	11
1367	55.0	443	1.63	14.99	.79	16.62	18.97	.10	3.45	434	23
1368	60.0	441	2.23	18.69	.94	20.92	19.88	.11	4.51	414	21
1523	64.9	442	2.35	18.50	.66	20.85	28.03	.11	4.70	394	14
1369	65.0	445	2.83	19.48	1.09	22.31	17.87	.13	5.01	389	22
1370	70.0	441	3.48	19.35	1.21	22.83	15.99	.15	4.75	407	25
1371	75.0	448	4.05	24.61	1.15	28.66	21.40	.14	6.47	380	18
1524	75.1	449	2.59	17.05	1.07	19.64	15.93	.13	6.40	266	17
1372	80.0	446	5.68	20.99	1.16	26.67	18.09	.21	5.49	382	21
1373	85.0	447	1.64	6.13	1.07	7.77	5.73	.21	2.57	239	42
1525	89.9	446	3.28	8.15	.77	11.43	10.58	.29	3.52	232	22
1374	90.0	453	2.71	7.66	1.22	10.37	6.28	.26	3.35	229	36
1375	95.0	431	8.25	10.37	1.12	18.62	9.26	.44	3.39	306	33
1526	95.1	435	7.15	9.46	.74	16.61	12.78	.43	3.86	245	19
1376	100.0	412	5.78	5.37	1.09	11.15	4.93	.52	1.72	312	63
1377	105.0	424	5.51	6.31	1.21	11.82	5.21	.47	2.14	295	57
1378	110.0	441	3.75	7.11	1.26	10.86	5.64	.35	3.42	208	37
1379	115.0	426	1.77	2.62	1.04	4.39	2.52	.40	1.66	158	63
1527	115.1	422	1.87	3.09	.72	4.96	4.29	.38	2.02	153	36
1380	120.0	410	3.12	2.99	1.26	6.11	2.37	.51	1.45	206	87
1381	125.0	420	.80	2.10	1.11	2.90	1.89	.28	2.83	74	39
1528	125.1	412	4.59	6.01	.87	10.60	6.91	.43	3.04	198	29
1382	130.0	419	.82	2.15	1.26	2.97	1.71	.28	1.61	134	78
1383	140.0	422	0.00	0.00	.83	0.00	0.00	.	0.00		
1384	150.0	376	.02	.06	.54	.08	.11	.25	0.00		
1385	160.0	323	.01	.03	.33	.04	.09	.25	0.00		
1386	170.0	239	0.00	0.00	.14	0.00	0.00	.	0.00		
1387	180.0	279	0.00	.01	.09	.01	.11	0.00	0.00		
1388	190.0	318	.01	.03	.07	.04	.43	.25	0.00		
1389	200.0	421	.69	.41	.46	1.10	.89	.63	0.00		
1390	205.0	411	3.04	4.72	.60	7.76	7.87	.39	2.54	186	24
1529	205.1	409	2.51	4.87	1.47	7.38	3.31	.34	3.06	159	48
1391	210.0	442	.06	.14	.09	.20	1.56	.30	0.00		
1392	211.0	389	.03	.09	.02	.12	4.50	.25	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: URAPUNGA NO 4

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MCMINN											
3157	18.8	445	.03	.06	.05	.09	1.20	.33	0.00		
3158	26.4	348	.03	.10	.07	.13	1.43	.23	0.00		
3159	32.3	488	.03	.29	.07	.32	4.14	.09	0.00		
3160	39.7	420	.11	.30	.05	.41	6.00	.27	0.00		
FORMATION: VELKERRIE											
3161	46.9	455	.02	.14	.01	.16	14.00	.13	0.00		
3162	74.4	440	.36	1.06	.01	1.42	.	.25	.62	171	2
3163	80.8	444	.46	.86	0.00	1.32	.	.35	.48	179	0
3164	92.6	442	.73	2.62	0.00	3.35	.	.22	.95	276	0
3165	132.6	439	3.85	28.18	.40	32.03	70.45	.12	6.61	426	6
3166	134.4	439	2.83	22.97	.53	25.80	43.34	.11	5.31	433	10
3167	137.6	440	3.69	31.57	.75	35.26	42.09	.10	7.51	420	10
3168	144.8	437	2.04	11.03	.86	13.07	12.83	.16	2.64	418	33
3169	145.6	437	2.67	12.59	1.04	15.26	12.11	.17	3.41	369	30
3170	148.1	439	3.54	19.45	1.15	22.99	16.91	.15	4.61	422	25
2467	155.6	443	4.88	23.73	.29	28.61	81.83	.17	5.28	449	5
2468	155.7	411	1.18	1.54	0.00	2.72	.	.43	.67	230	0
3171	157.3	439	5.70	37.16	1.24	42.86	29.97	.13	8.68	428	14
3172	160.0	440	4.04	21.95	1.08	25.99	20.32	.16	5.27	417	20
3173	163.7	444	3.51	24.37	1.18	27.88	20.65	.13	5.87	415	20
3174	168.1	444	4.96	16.31	.87	21.27	18.75	.23	4.15	393	21
3175	173.0	444	4.78	11.70	1.04	16.48	11.25	.29	3.15	371	33
3176	175.0	443	4.69	12.97	1.12	17.66	11.58	.27	3.54	366	32
3177	175.5	443	5.11	13.71	1.20	18.82	11.43	.27	3.49	393	34
3178	206.5	448	4.05	17.93	1.18	21.98	15.19	.18	4.81	373	25
3179	209.5	439	3.03	12.06	1.23	15.09	9.80	.20	3.82	316	32
3180	216.9	445	3.26	11.25	1.34	14.51	8.40	.22	3.88	290	35
3181	236.0	451	.01	.07	.83	.08	.08	.13	0.00		
3182	258.5	385	.01	.10	.51	.11	.20	.09	0.00		
3183	302.7	413	.01	.12	.25	.13	.48	.08	0.00		
3184	312.0	457	.42	.84	.13	1.26	6.46	.33	.70	120	19
3185	320.0	448	.54	.39	0.00	.93	.	.58	0.00		
3186	324.6	449	3.65	15.83	.62	19.48	25.53	.19	5.81	272	11
3187	327.5	451	4.05	15.88	.90	19.93	17.64	.20	5.71	278	16
3188	331.5	451	4.30	6.07	1.13	10.37	5.37	.41	2.62	232	43
3189	339.0	461	.28	.47	.58	.75	.81	.37	.48	98	121
3190	342.7	427	7.60	6.68	.98	14.28	6.82	.53	2.01	332	49
2469	346.5	416	16.79	11.41	.38	28.20	30.03	.60	2.91	392	13
3191	348.2	447	2.60	2.72	.88	5.32	3.09	.49	3.31	82	27
3192	351.1	451	2.63	3.26	.49	5.89	6.65	.45	1.64	199	30
3193	354.7	448	3.65	4.59	.67	8.24	6.85	.44	2.02	227	33
3194	357.0	448	3.39	4.19	.88	7.58	4.76	.45	2.23	188	39
3195	360.3	447	3.09	3.64	1.06	6.73	3.43	.46	2.13	171	50
3196	369.5	459	.31	.57	.22	.88	2.59	.35	.47	121	47
FORMATION: CORCORAN											
3197	410.1	453	0.00	.07	0.00	.07	.	0.00	0.00		
3199	421.3	396	.01	.05	.06	.06	.83	.17	0.00		
3198	433.4	459	.03	.15	.24	.18	.63	.17	.29	52	83
3200	463.8	346	0.00	.08	.01	.08	8.00	0.00	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: URAPUNGA NO 5

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: JALBOI MBR											
3211	117.4	436	0.00	.03	0.00	.03	.	0.00	0.00		
3212	119.1	382	0.00	.01	0.00	.01	.	0.00	0.00		
3213	123.0	275	.02	.01	0.00	.03	.	.67	0.00		
3214	123.7	300	0.00	.01	0.00	.01	.	0.00	0.00		
3216	140.0	275	.01	.02	0.00	.03	.	.33	0.00		
FORMATION: MAINORU											
3217	148.9	275	.03	.03	0.00	.06	.	.50	.27	11	0
3219	323.5	346	.01	.03	0.00	.04	.	.25	0.00		
3218	325.1	327	0.00	.02	0.00	.02	.	0.00	0.00		
3220	326.1	352	.01	.03	0.00	.04	.	.25	0.00		
3221	348.1	389	.01	.08	0.00	.09	.	.11	.32	25	0
3222	360.1	401	.02	.07	0.00	.09	.	.22	0.00		
3224	378.6	375	.01	.07	0.00	.08	.	.13	0.00		
3223	387.3	409	.02	.10	0.00	.12	.	.17	.36	28	0
3225	405.4	358	.01	.05	0.00	.06	.	.17	0.00		
3226	408.7	389	.02	.08	0.00	.10	.	.20	0.00		
3227	420.0	338	.02	.04	0.00	.06	.	.33	0.00		
3228	485.9	344	.01	.04	0.00	.05	.	.20	0.00		
3229	536.7	377	.01	.06	0.00	.07	.	.14	0.00		
3230	541.1	443	.01	.09	0.00	.10	.	.10	0.00		
3231	560.1	460	.15	.19	0.00	.34	.	.44	.56	34	0
3232	567.6	456	.11	.13	0.00	.24	.	.46	.40	33	0
3233	569.1	420	.06	.09	0.00	.15	.	.40	0.00		
3234	574.0	330	.08	.08	0.00	.16	.	.50	0.00		
3235	583.5	411	.12	.14	0.00	.26	.	.46	.45	31	0
3236	590.1	445	.17	.17	0.00	.34	.	.50	.52	33	0
3237	599.0	406	.02	.04	0.00	.06	.	.33	0.00		
3238	603.8	311	.03	.06	0.00	.09	.	.33	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: WF7

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
1709	190.2	445	.21	.20	.22	.41	.91	.51	.82	24	27
1712	197.0	444	.20	.21	.17	.41	1.24	.49	.85	25	20

BASIN/AREA: MCARTHUR

WELL/LOCALITY: WM6

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: BARNEY CREEK											
3034	104.2	462	.61	.46	.08	1.07	5.75	.57	1.22	38	7
3035	200.8	484	.64	.50	.12	1.14	4.17	.56	1.87	27	6
3036	294.0	450	.02	.04	.03	.06	1.33	.33	0.00		
3037	423.6	415	.03	.10	.01	.13	10.00	.23	0.00		
3038	519.3	334	.02	.04	0.00	.06	.	.33	0.00		

BASIN/AREA: MCARTHUR

WELL/LOCALITY: X28

ID	DEPTH M	TMAX DEG C	S1 .....KG per TONNE.....	S2	S3	S1+S2	S2/S3	PI	TOC %	HI	OI
FORMATION: MCMINN											
3130	16.9	432	.18	4.65	.37	4.83	12.57	.04	1.15	404	32
3131	32.0	433	.36	7.08	1.46	7.44	4.85	.05	1.85	383	79
3132	39.9	430	.18	4.13	.46	4.31	8.98	.04	1.27	325	36
3133	50.3	432	.24	2.41	2.96	2.65	.81	.09	1.00	241	296
3134	52.4	433	.12	2.95	6.97	3.07	.42	.04	1.28	230	545
3135	54.3	434	.12	2.23	4.82	2.35	.46	.05	.91	245	530
3136	59.4	433	.05	1.37	1.54	1.42	.89	.04	.59	232	261
3137	60.7	435	.10	2.18	7.13	2.28	.31	.04	1.03	212	692
3138	61.0	435	.12	2.38	7.22	2.50	.33	.05	1.17	203	617
3139	63.7	435	.07	1.86	10.21	1.93	.18	.04	1.02	182	1001
3140	70.7	435	.05	.65	.32	.70	2.03	.07	.62	105	52
3141	74.1	437	.05	1.28	.52	1.33	2.46	.04	.72	178	72
3142	82.9	436	.09	1.15	.24	1.24	4.79	.07	.52	221	46
3352	83.2	440	.50	1.84	.04	2.34	46.00	.21	.38	484	11

APPENDIX O**SOLUBLE EXTRACT AND HYDROCARBON YIELDS****Abbreviations:**

PPM = parts per million

MG/G ORG C = milligrams per gram of organic carbon

SAT/AROM = ratio of saturated to aromatic hydrocarbons

Full well and stratigraphic names are given in Appendices A and B.

Note: wells arranged only in alphabetical order.

BASIN: MCARTHUR

WELL: 82/1

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: LANSEN CREEK SH							
1638	412.8	1.49	981	318	21.3	32.4	1.78
1639	424.0	.90	1655	713	79.2	43.1	1.72
1640	427.8	.91	2951	1864	204.9	63.2	2.04

BASIN: MCARTHUR

WELL: 82/6

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS MG/G ORG C % IN SAT/AROM EXTRACT		
FORMATION:				YALCO			
1531	88.0	1.36	692	207	15.2	29.9	.37
1532	94.1	.84	649	226	26.8	34.8	.62
1548	124.9	1.61	467	57	3.5	12.1	.31
1169	125.7	5.37	3793	1799	33.5	47.4	.39
FORMATION:				LYNOTT-DON			
1551	290.3	1.21	797	288	23.8	36.1	1.56

BASIN: MCARTHUR

WELL: 82/7

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS MG/G ORG C % IN SAT/AROM EXTRACT		
FORMATION: BALBARINI							
1542	54.2	.61	1758	542	88.9	30.8	.47
FORMATION: YALCO							
1172	186.3	3.99	868	396	9.9	45.7	.46
1173	187.2	3.15	850	307	9.7	36.1	.09

BASIN: MCARTHUR

WELL: 82/8

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS MG/G ORG C % IN SAT/AROM EXTRACT		
FORMATION: LANSEN CREEK SH							
1641	67.4	.42	246	39	9.2	15.7	1.71

BASIN: MCARTHUR

WELL: B8

ID	DEPTH FT	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS			SAT/AROM
					MG/G	ORG C	% IN EXTRACT	
FORMATION: MCMINN								
3122	57.0	2.96	2539	881	29.8		34.7	3.63
3127	195.0	1.06	89	81	7.7		91.7	.57

BASIN: MCARTHUR

WELL: BC3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS			SAT/AROM
					MG/G	ORG C	% IN EXTRACT	
FORMATION: BARNEY CREEK								
1731	292.0	.74	82	0	0.0		0.0	.

BASIN: MCARTHUR

WELL: BJ1

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS			SAT/AROM
					MG/G	ORG C	% IN EXTRACT	
FORMATION: BARNEY CREEK								
2976	30.6	1.90	636	385	20.3		60.6	2.22

BASIN: MCARTHUR

WELL: BJ3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS			SAT/AROM
					MG/G	ORG C	% IN EXTRACT	
FORMATION: LYNOTT-CAR								
2977	26.5	4.57	2071	1071	23.4		51.7	.
FORMATION: BARNEY CREEK								
2979	62.8	2.89	1279	349	12.1		27.3	4.00

BASIN: MCARTHUR

WELL: BROADMERE NO 1

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: LANSEN CREEK SH							
2007	36.6	2.98	1188	593	19.9	49.9	.63
2011	240.0	2.45	4188	2018	82.4	48.2	1.67
2014	330.0	3.54	3343	1918	54.2	57.4	1.86
2021	450.0	4.18	2099	1318	31.5	62.8	1.38
2071	1110.0	3.44	1428	909	26.4	63.6	3.16
FORMATION: AGNER SST							
2199	1505.7	1.44	91	27	1.9	29.3	.71

BASIN: MCARTHUR

WELL: CA1

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1657	337.6	9.08	123	55	.6	45.0	1.25

BASIN: MCARTHUR

WELL: CA2

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1665	625.9	.53	120	59	11.1	48.9	2.35

BASIN: MCARTHUR

WELL: CA3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1672	481.4	0.00	19	0	.	0.0	.

BASIN: MCARTHUR

WELL: GR3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
2836	30.1	2.82	2500	1118	39.6	44.7	2.80

BASIN: MCARTHUR

WELL: GR5

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
2861	72.5	4.64	1761	1029	22.2	58.5	1.29

BASIN: MCARTHUR

WELL: GR7

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
2887	38.7	1.15	810	327	28.5	40.4	1.47
2889	50.3	4.97	3698	1814	36.5	49.1	1.60
2897	238.8	5.17	4200	1800	34.8	42.9	2.18
2911	601.5	1.25	2434	1379	110.3	56.7	3.06
2917	794.6	1.54	1525	997	64.7	65.4	2.95
1674	854.0	3.67	1815	998	27.2	55.0	1.37
2919	866.5	2.81	2278	1399	49.8	61.4	1.75
1676	875.8	2.57	1808	1023	39.8	56.6	1.08

BASIN: MCARTHUR

WELL: GR8

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
2926	49.2	3.11	1926	722	23.2	37.5	1.29
2943	425.9	1.00	1353	712	71.2	52.6	2.14
2950	570.8	4.18	1100	647	15.5	58.8	1.15

BASIN: MCARTHUR

WELL: GR9

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1678	422.2	1.54	714	326	21.2	45.7	1.45
1682	500.1	3.57	1145	525	14.7	45.9	1.61

BASIN: MCARTHUR

WELL: GR10

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
3048	37.4	1.90	2222	834	43.9	37.5	1.53
1809	88.4	3.00	4995	2610	87.0	52.2	1.77
1810	143.3	4.68	1478	761	16.3	51.5	1.06
1811	170.3	1.30	3504	2337	179.8	66.7	2.03
1812	182.8	2.95	1757	1157	39.2	65.9	1.71
1813	232.8	4.50	1964	1022	22.7	52.0	1.47
1830	297.2	.90	2370	1317	146.3	55.6	1.77
1831	360.0	.31	621	287	92.7	46.3	2.29
1832	410.0	.21	590	299	142.4	50.7	3.01
1833	443.0	.80	1678	894	111.7	53.3	3.88
1835	481.4	1.04	2000	778	74.8	38.9	1.66
1837	527.7	.52	1009	617	118.7	61.2	3.76
1841	571.6	1.22	1628	790	64.8	48.6	1.07
1843	587.3	.83	1131	798	96.1	70.5	3.12
1846	602.5	2.76	1657	1016	36.8	61.3	3.07
1849	630.0	.69	1956	1196	173.3	61.1	9.68
1855	662.1	.69	131	97	14.1	74.3	5.82

BASIN: MCARTHUR

WELL: GR11

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1860	178.9	1.90	803	357	18.8	44.4	1.71
1865	253.8	2.15	444	235	10.9	52.9	2.24
1873	347.3	1.80	850	385	21.4	45.3	1.83
1880	415.2	5.38	682	442	8.2	64.9	1.60
1887	441.9	1.70	1070	1057	62.2	98.8	.76

BASIN: MCARTHUR

WELL: M2

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		SAT/AROM
					MG/G ORG C	% IN EXTRACT	
FORMATION: BARNEY CREEK							
1699	130.3	1.19	683	432	36.3	63.3	3.61
1746	355.2	.95	82	30	3.2	36.9	1.58

BASIN: MCARTHUR

WELL: M3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		SAT/AROM
					MG/G ORG C	% IN EXTRACT	
FORMATION: BARNEY CREEK							
1701	145.1	2.11	336	192	9.1	57.2	1.53
1740	334.6	.65	63	0	0.0	0.0	.

BASIN: MCARTHUR

WELL: M13

ID	DEPTH FT	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		SAT/AROM
					MG/G ORG C	% IN EXTRACT	
FORMATION: MCMINN							
3147	225.0	1.62	962	236	14.6	24.5	.70
3149	259.0	1.53	229	77	5.0	33.7	1.21

BASIN: MCARTHUR

WELL: M17/08

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		SAT/AROM
					MG/G ORG C	% IN EXTRACT	
FORMATION: BARNEY CREEK							
1698	126.6	3.20	113	22	.7	19.4	3.00
1702	147.8	2.97	37	0	0.0	0.0	.
1717	269.8	.55	43	0	0.0	0.0	.
1720	278.6	.61	39	0	0.0	0.0	.
1723	282.1	.66	33	0	0.0	0.0	.
1735	311.5	.64	46	0	0.0	0.0	.
1741	320.6	.70	10	0	0.0	0.0	.
1743	339.5	.56	30	0	0.0	0.0	.

BASIN: MCARTHUR

WELL: MCA5

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
3026	74.0	1.72	1216	580	33.7	47.7	4.58
3030	306.4	1.22	577	235	19.2	40.7	.

BASIN: MCARTHUR

WELL: MCA10

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
3032	27.8	4.05	448	237	5.9	53.0	2.05

BASIN: MCARTHUR

WELL: MY4

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
3014	56.1	1.79	1204	547	30.6	45.5	3.50

BASIN: MCARTHUR

WELL: MY5

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: REWARD DOLOMITE							
3017	67.2	3.65	1921	799	21.9	41.6	3.08

BASIN: MCARTHUR

WELL: N27/63

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1694	105.5	1.98	247	126	6.4	50.9	1.01
1696	116.4	.56	137	24	4.3	17.8	2.60
1705	172.8	2.75	225	66	2.4	29.2	1.21
1713	223.2	.88	125	29	3.3	23.0	4.00
1718	276.0	.71	313	192	27.0	61.3	3.64
1724	289.6	.79	39	0	0.0	0.0	.
1736	313.0	.51	16	0	0.0	0.0	.
1742	335.1	.68	14	0	0.0	0.0	.
1749	381.0	.34	42	0	0.0	0.0	.

BASIN: MCARTHUR

WELL: T19

ID	DEPTH FT	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: MCMINN							
3152	71.3	1.37	1592	293	21.4	18.4	.47

BASIN: MCARTHUR

WELL: URAPUNGA NO 3

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: VELKERRI							
1522	39.9	7.20	3355	2197	30.5	65.5	2.95
1523	64.9	4.70	3321	2029	43.2	61.1	3.13
1524	75.1	6.40	3865	1733	27.1	44.8	2.54
1525	89.9	3.52	6729	4010	113.9	59.6	3.05
1526	95.1	3.86	12773	7982	206.8	62.5	2.57
1527	115.1	2.02	2761	1440	71.3	52.1	2.23
1528	125.1	3.04	9143	3528	116.0	38.6	1.28
1529	205.1	3.06	6201	3540	115.7	57.1	3.53

BASIN: MCARTHUR

WELL: URAPUNGA NO 4

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: VELKERRI							
3165	132.6	6.61	5276	3786	57.3	71.7	.59
2467	155.6	5.28	5892	4118	78.0	69.9	.88
2468	155.7	.67	2482	1247	186.1	50.2	.85
3171	157.3	8.68	7332	5456	62.9	74.4	.59
3174	168.1	4.15	1960	1001	24.1	51.0	2.41
3180	216.9	3.88	5005	3189	82.2	63.7	1.62
3186	324.6	5.81	7471	5299	91.2	70.9	1.80
3190	342.7	2.01	17842	13387	666.0	75.0	3.17
2469	346.5	2.91	30011	24219	832.3	80.7	2.58
3195	360.3	2.13	3381	2278	107.0	67.4	2.80

BASIN: MCARTHUR

WELL: WF7

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
1709	190.2	.82	202	0	0.0	0.0	.

BASIN: MCARTHUR

WELL: WM6

ID	DEPTH M	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: BARNEY CREEK							
3035	200.8	1.87	374	112	6.0	29.8	3.67

BASIN: MCARTHUR

WELL: X28

ID	DEPTH FT	ORG C %	EXTRACT .....PPM.....	HC'S	HYDROCARBONS		
					MG/G ORG C	% IN EXTRACT	SAT/AROM
FORMATION: MCMINN							
3131	105.0	1.85	2667	338	18.3	12.7	1.37
3138	200.0	1.17	788	169	14.4	21.4	.39

APPENDIX P

AROMATIC MATURATION INDICES

Abbreviations:

DMI = dimethylnaphthalene index

$$\text{DMI-1} = 2,6, + 2,7, / 1,5$$

$$\text{DMI-2} = -\log(1,8/2,6 + 2,7 + 1,3 + 1,7 + 1,6 + 1,4 + 2,3 + 1,5 + 1,2 + 1,8)$$

where the numbers refer to the 1,8- 2,6- 2,7- 1,3- 1,7- 1,6- 1,4- 2,3- 1,5- and 1,2- dimethylnaphthalene isomers.

TNI = trimethylnaphthalene index

$\text{TNI} = 1,4,6 + 1,3,5, / 2,3,6$ where the numbers refer to the 1,4,6- 1,3,5,- and 2,3,6- trimethylnaphthalene isomers.

MPI + methylphenanthrene index

$$\text{MPI-1} = 1.5 \times (3, + 2,) / (9, + 1. + P)$$

$$\text{MPI-2} = 3 \times 2, / (9, = 1, + P)$$

where the numbers refer to the 1- 2- 3- and 9-methylphenanthrene isomers and P = phenanthrene.

DPI = dimethylphenanthrene index

$$\text{DPI} = 1 + 2 + 3 + 4 + / P + 5 + 6 + 7$$

where the numbers refer to unidentified dimethylphenanthrene isomers figured by Radke and Welte (1983) and P = phenanthrene.

Full well and stratigraphic names are given in Appendix A.

Note: wells are arranged only in alphabetical order.

BASIN: MCARTHUR

WELL: 82/6

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: YALCO							
1531	88.0	.	.	.	.65	.57	1.24
1532	94.1	.	.	.	.62	.61	1.74
1169	125.7	.	.	.	.78	.80	1.38
FORMATION: LYNOTT-DON							
1551	290.3	.	.	.	.79	.82	1.07

BASIN: MCARTHUR

WELL: 82/7

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
1542	54.2	.	FORMATION:	BALBARINI	.	.	.
		.	FORMATION:	YALCO	.26	.32	.65
1172	186.3	.	.	.	.99	1.02	1.36

BASIN: MCARTHUR

WELL: 82/8

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: LANSEN CREEK SH							
1641	67.4	.	.	.	.91	.94	1.43

BASIN: MCARTHUR

WELL: GR7

ID	DEPTH	AROMATIC MATURATION INDICES					
	M	DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
2887	38.7	.	.	.	.88	1.01	1.88
2889	50.3	.	.	.	.63	.67	.91
2897	238.8	.	.	.	.54	.56	.68
2911	601.5	.	.	.	.75	.79	.79
2917	794.6	.	.	.	.76	.86	.77
1674	854.0	.	.	.	.87	.97	.86
2919	866.5	.	.	.	.89	.99	.94
1676	875.8	.	.	.	.92	1.04	1.13

BASIN: MCARTHUR

WELL: GR10

ID	DEPTH	AROMATIC MATURATION INDICES					
	M	DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
3048	37.4	.	.	.	.61	.61	.87
1809	88.4	1.6	0.0	1.43	.57	.57	.78
1810	143.3	2.3	3.0	1.31	.60	.61	.76
1812	182.8	2.3	3.2	.	.58	.59	.84
1813	232.8	1.7	3.2	1.85	.52	.54	.71
1830	297.2	1.7	0.0	.	.62	.65	.83
1831	360.0	.	.	.	.75	.82	1.06
1832	410.0	1.9	2.5	1.49	.73	.82	1.20
1833	443.0	2.7	0.0	1.68	.70	.74	.76
1835	481.4	1.8	0.0	.	.72	.77	.78
1837	527.7	2.4	2.1	1.35	.73	.80	.78
1841	571.6	.8	2.3	1.46	.73	.81	.71
1843	587.3	1.8	2.3	1.18	.73	.82	.72
1846	602.5	2.7	0.0	.	.77	.85	.78
1849	630.0	1.4	2.1	1.35	.77	.87	.77
1855	662.1	.	.	.	.83	.92	1.11

BASIN: MCARTHUR

WELL: GR11

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
1860	178.9	.	.	.	.61	.63	.80
1865	253.8	.	.	.	.66	.69	.85
1873	347.3	.	.	.	.69	.75	.81
1880	415.2	.	.	.	.80	.87	.91
1887	441.9	.	.	.	.85	.86	.84

BASIN: MCARTHUR

WELL: M2

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
1699	130.3	.	.	.	1.41	1.56	1.61
1746	355.2	.	.	.	1.51	1.67	1.85

BASIN: MCARTHUR

WELL: M3

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
1701	145.1	.	.	.	1.00	1.10	1.13

BASIN: MCARTHUR

WELL: M17/08

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
1698	126.6	.	.	.	1.93	2.25	2.48

BASIN: MCARTHUR

WELL: N27/63

ID	DEPTH M	AROMATIC MATURATION INDICES					
		DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: BARNEY CREEK							
1694	105.5	.	.	.	1.89	2.19	2.28
1696	116.4	.	.	.	1.99	2.30	2.32
1705	172.8	.	.	.	2.19	2.56	2.71
1713	223.2	.	.	.	2.64	3.30	3.05
1718	276.0	.	.	.	2.39	2.87	3.06

BASIN: MCARTHUR

WELL: URAPUNGA NO 3

ID	DEPTH	AROMATIC MATURATION INDICES					
	M	DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: VELKERRI							
1522	39.9	1.8	0.0	.	.66	.50	.76
1523	64.9	2.3	2.7	1.30	.79	.54	.80
1524	75.1	.	.	.	.90	.53	.78
1525	89.9	1.8	0.0	1.18	1.13	.75	.85
1526	95.1	2.0	0.0	.	1.16	.62	.95
1527	115.1	.	.	.57	1.39	.66	.90
1528	125.1	.	.	1.02	.95	1.07	.97
1529	205.1	.	.	.95	1.34	1.24	1.86

BASIN: MCARTHUR

WELL: URAPUNGA NO 4

ID	DEPTH	AROMATIC MATURATION INDICES					
	M	DMI-1	DMI-2	TNI	MPI-1	MPI-2	DPI
FORMATION: VELKERRI							
3165	132.6	.	.	.	.73	.75	.78
2467	155.6	.	.	.	.75	.80	.84
2468	155.7	.	.	.	.75	.83	.87
3171	157.3	.	.	.	.79	.84	.77
3180	216.9	.	.	.	.84	.91	.86
3186	324.6	.	.	.	1.30	1.24	1.43
3190	342.7	.	.	.	1.03	1.15	1.01
2469	346.5	.	.	.	1.38	1.39	2.02
3195	360.3	.	.	.	1.43	1.65	1.50

APPENDIX Q

ELEMENTAL ANALYSES OF ISOLATED KEROGENS

BASIN: MCARTHUR

WELL: 82/1

ID	DEPTH M	C	H PERCENT	N DRY	O ASH	S	H/C	O/C	ASH %	FE %
FORMATION: LANSEN CREEK SH										
1638	412.8	55.04	5.70	.25	25.95	13.06	1.24	.35	38.00	0.00
1639	424.0	66.40	5.52	.69	33.63	-6.23	1.00	.38	16.70	9.50
1640	427.8	80.83	5.99	1.11	7.38	4.69	.89	.07	12.80	0.00

BASIN: MCARTHUR

WELL: 82/6

ID	DEPTH M	C	H PERCENT	N DRY	O ASH	S	H/C	O/C	ASH %	FE %
FORMATION: YALCO										
1531	88.0	80.96	6.24	.66	10.20	1.94	.92	.09	19.40	2.00
1532	94.1	77.89	7.73	.39	9.90	4.08	1.19	.10	33.20	0.00
1548	124.9	80.70	6.13	.80	0.00	12.37	.91	0.00	19.10	0.00
1169	125.7	83.39	7.81	.74	17.42	-9.36	1.12	.16	18.60	11.70
FORMATION: LYNOTT-DON										
1551	290.3	78.63	6.17	1.11	8.80	5.28	.94	.08	13.90	0.00

BASIN: MCARTHUR

WELL: 82/7

ID	DEPTH M	C	H PERCENT	N DRY	O ASH	S	H/C	O/C	ASH %	FE %
FORMATION: BALBARINI										
1542	54.2	86.95	7.19	.51	7.27	-1.92	.99	.06	8.20	3.00
FORMATION: YALCO										
1172	186.3	81.00	5.98	.76	9.96	2.31	.89	.09	17.80	3.00
1173	187.2	80.75	6.27	.88	8.65	3.46	.93	.08	17.80	5.00

BASIN: MCARTHUR

WELL: 82/8

ID	DEPTH M	C	H PERCENT	N DRY	O ASH	S	H/C	O/C	ASH %	FE %
FORMATION: LANSEN CREEK SH										
1641	67.4	69.41	3.47	.97	22.90	3.25	.60	.25	34.60	0.00

BASIN: MCARTHUR

WELL: GR10

ID	DEPTH M	C	H	N	O	S	H/C	O/C	ASH %	FE %
			PERCENT DRY			ASH FREE				
			FORMATION: BARNEY CREEK							
1809	88.4	73.68	10.19	4.17	7.63	4.34	1.66	.08	9.60	4.78
1810	143.3	78.14	10.51	3.61	9.32	-1.58	1.61	.09	5.80	5.00
1812	182.8	78.86	9.78	4.71	0.00	6.65	1.49	0.00	0.00	0.00
1813	232.8	77.74	10.01	3.24	6.39	2.62	1.54	.06	5.51	2.70
1830	297.2	73.62	9.28	2.21	10.60	4.28	1.51	.11	19.60	10.20
1831	360.0	83.89	8.62	3.74	0.00	3.75	1.23	0.00	0.00	0.00
1832	410.0	78.27	7.48	3.05	0.00	11.20	1.15	0.00	18.20	0.00
1833	443.0	83.78	6.49	3.55	0.00	6.18	.93	0.00	9.10	0.00
1835	481.4	76.97	7.12	3.14	10.04	2.74	1.11	.10	7.20	3.00
1837	527.7	71.71	5.81	3.51	14.06	4.91	.97	.15	16.20	0.00
1841	571.6	87.66	6.68	3.89	0.00	1.78	.91	0.00	3.90	0.00
1843	587.3	75.25	6.27	2.24	9.32	6.91	1.00	.09	17.00	8.00
1846	602.5	82.23	5.99	1.29	9.04	1.46	.87	.08	3.60	1.26

BASIN: MCARTHUR

WELL: N27/63

ID	DEPTH	C	H	N	O	S	H/C	O/C	ASH	FE
	M		PERCENT	DRY	ASH	FREE			%	%
			FORMATION: BARNEY CREEK							
1694	105.5	79.32	3.92	.56	11.24	4.96	.59	.11	10.60	4.60
1696	116.4	52.67	3.41	.88	0.00	43.04	.78	0.00	31.30	0.00
1705	172.8	75.11	5.44	1.74	19.24	-1.53	.87	.19	5.90	3.40
1713	223.2	83.72	4.34	.95	13.03	-2.04	.62	.12	10.60	9.00
1718	276.0	72.42	2.28	.75	13.18	11.37	.38	.14	42.80	20.00
1724	289.6	81.32	2.57	2.67	0.00	13.44	.38	0.00	13.40	0.00
1736	313.0	4.83	.81	.87	33.70	59.79	2.02	5.23	72.00	.65
1742	335.1	15.12	1.41	.63	78.67	4.16	1.12	3.90	5.80	1.13

BASIN: MCARTHUR

WELL: URAPUNGA NO 3

ID	DEPTH	C	H	N	O	S	H/C	O/C	ASH	FE
	M		PERCENT	DRY	ASH	FREE			%	%
			FORMATION:		VELKERRI					
1522	39.9	86.57	7.26	.74	4.52	.91	1.01	.04	7.00	3.95
1523	64.9	88.98	6.52	.79	3.80	-.09	.88	.03	5.90	1.55
1524	75.1	87.79	6.28	.97	3.80	1.17	.86	.03	3.80	1.73
1525	89.9	87.44	5.74	1.12	5.03	.68	.79	.04	9.30	3.35
1526	95.1	89.05	5.65	1.12	4.25	-.06	.76	.04	8.80	2.05
1527	115.1	89.68	5.26	1.38	4.04	-.35	.70	.03	5.80	2.35
1528	125.1	88.57	4.81	.87	4.80	.95	.65	.04	7.20	1.73

APPENDIX R

PLATE 1

PLATE 1

(a) The Abner Sandstone (Roper Group) near Beetle Springs, where it forms the eastern escarpment of the Abner Range, 80 km south-southwest of Borroloola.

(b) Measuring down-hole temperatures of Amoco's DDH 82/7 near Beetle Springs.

(c) Leitz Orthoplan-Pol microscope with MPV1 photometer and associated transformers in foreground, and a modified Leitz Planphot microscope with zenon lamp and associated transformers in background used for low-power fluorescence microscopy.

PLATE 2

Probable microfossils, McArthur Basin.

PLATE 2

Probable microfossils, McArthur Basin.

- a) Roper Group, Mainoru Formation; DDH 82/8, 66.8 m; a double strand of silvery organic matter which is probably part of a large acritarch; mean maxRo% = 2.21; perpendicular to bedding; plane-polarized reflected white light; field-width = 0.10 mm;
- b) Roper Group, Corcoran Formation; DDH Urapunga 4, 463.8 m; group of pyritized ?coccoids; perpendicular to bedding; plane-polarized reflected white light; scale bar = 20 microns;
- c) McArthur Group, Barney Creek Formation; DDH M17/08, 351.4 m; pyritized clusters of cells; perpendicular to bedding; plane-polarized reflected white light; field-width = 0.20 mm;
- d) McArthur Group, Barney Creek Formation; DDH GR10, 80.1 m; small tetrad of cells within circled area; fluorescence mode; parallel to bedding; scale bar = 20 microns.

PLATE 2

PLATE 3

**Fluorescent lamalginite from the Barney Creek
Formation, Glyde River Subbasin, DDH's GR3, 5 & 7; low
magnification photomicrographs.**

PLATE 3

Fluorescent lamalginites from the Barney Creek Formation, Glyde River Subbasin, DDH's GR3, 5 & 7; low magnification photomicrographs.

- a) A large lenticular lamalginites body in very fine-grained calcarenite underlain by small discrete lamalginites in calcilutite; DDH GR3, 30.1 m; perpendicular to bedding, fluorescence mode, field width = 2.0 mm.
- b) A band of wavy filamentous lamalginites in very fine-grained calcarenite, DDH GR5, 213.9 m; perpendicular to bedding, field width = 3.4 mm, plane-polarized white reflected light.
- c) As for b) but in fluorescence mode.
- d) Part of large body of lamalginites in central area with smaller discrete lamalginites from DDH GR5, 72.5 m, perpendicular to bedding; field width = 2.0 mm; plane-polarized white reflected light; mean maxRo% = 0.12%.
- e) As for d) but in fluorescence mode.
- f), g) As for d) and e) but showing one end of the same large body of lamalginites.
- h) Small discrete lamalginites bodies from DDH GR7, 180.0m; field width = 2.0 mm; fluorescence mode; perpendicular to bedding;
- i) Small discrete lamalginites in calcilutite overlain by very fine-grained calcarenite showing strong mineral fluorescence, DDH GR7, 238.8m; fluorescence mode; field-width = 2.0 mm; perpendicular to bedding.

PLATE 4

**Fluorescent lamalginite from the Barney Creek
Formation, Glyde River Subbasin, DDH GR10, low
magnification photomicrographs.
All photomicrographs are in fluorescence mode.**

PLATE 4

Fluorescent lamalginites from the Barney Creek Formation, Glyde River Subbasin, DDH GR10, low magnification photomicrographs. All photomicrographs are in fluorescence mode.

- a) 23.2 m; discrete lamalginites bodies; perpendicular to bedding; field-width = 2.0 mm;
- b) 37.4 m; a large lenticular shaped lamalginites body in central area, discrete lamalginites of varying sizes surrounding it; perpendicular to bedding; field-width = 2.0 mm;
- c) 88.4 m; discrete lamalginites bodies of varying sizes, perpendicular to bedding; field-width = 2.0 mm;
- d) 88.4 m; parallel to bedding; irregular shaped bodies of lamalginites; field-width = 2.0 mm;
- e) 92.6 m; continuous lamalginites showing soft-sediment deformation and compaction around a carbonate grain; perpendicular to bedding; field-width = 2.0 mm;
- f) 137.2 m; lenticular mass of very fine-grained pyrite possibly replacing discoidal gypsum (central dark body) in fluorescing fine-grained calcarenite; perpendicular to bedding, field-width = 0.8 mm;
- g) 143.3 m; central discrete lenticular and wavy lamalginites body surrounded by smaller lamalginites bodies; perpendicular to bedding; field-width = 0.8 mm;
- h) 143.3 m; parallel to bedding; a single lamalginites body showing an irregular but roughly circular outline, field-width = 0.8 mm;
- i) 232.1 m; thin wavy lamalginites; perpendicular to bedding; field-width = 2.0 mm.

PLATE 5

**Fluorescent lamalginite from the Barney Creek
Formation, Glyde River Subbasin, DDH GR10, 88.4m -
442.9m.**

PLATE 5

Fluorescent lamalginite from the Barney Creek Formation, Glyde River Subbasin, DDH GR10, 88.4 m - 442.9 m.

All photomicrographs are at high magnifications and perpendicular to bedding.

a) 88.4 m; a strand of lamalginite viewed under plane-polarized reflected light; scale bar = 50 microns; mean maxRo% = 0.12%;

b) as for a) but in fluorescence mode; note thin lamellae in the large strand of lamalginite;

c) 143.3 m; part of a large lamalginite body showing individual lamellae and contained mineral matter, in fluorescence mode; scale bar = 20 microns;

d) 143.3 m; grey surface of part of a strand of lamalginite; plane-polarized reflected white light; scale bar = 20 microns; mean maxRo% = 0.14%;

e) as for d) but in fluorescence mode; scale bar = 20 microns;

f) 297.2 m; centrally located strand of grey reflecting lamalginite; plane-polarized white reflected light; scale bar = 20 microns; mean maxRo% = 0.24%;

g) as for f) but in fluorescence mode;

h) 410.0 m; a thin strand of lamalginite; scale bar = 20 microns; mean maxRo% = 0.27%.

i) as for f) but in fluorescence mode; note that the prominent mineral fluorescence; scale bar = 20 microns;

PLATE 5

PLATE 6

Low fluorescent lamalginite and bitumen from the
Barney Creek Formation, Glyde River Subbasin, DDH GR
10, 575.3 m.

PLATE 6

Low-fluorescent lamalginite and bitumen from the Barney Creek Formation, Glyde River Subbasin, DDH GR 10, 575.3 m.

All photos are perpendicular to bedding.

a) a low-magnification photomicrograph of calcilutite containing diffuse dark organic matter and one thucholite in upper right-hand corner, underlain by layer of relatively organic-matter free very fine grained calcarenite; white reflected light;

b) strand of lamalginite in central area under plane polarized white light; part of a large strand of lamalginite shown in composite photomicrograph d; mean maxRo% for fluorescent lamalginite = 0.40%;

c) same view as for b) but in fluorescence mode;

d) composite photo of a single discontinuous lamalginite body, plane-polarized reflected light.

e) a patch of dispersed bitumen in plane-polarized reflected light; scale bar is 20 microns;

f) the same patch of dispersed bitumen as for e) but in fluorescence mode; note the presence of zoned carbonate rhombs; bright yellow spots within the patch are oil inclusions.

PLATE 6

PLATE 7

**Bitumen in the Barney Creek Formation, Glyde River
Subbasin, DDH GR10.**

PLATE 7

Bitumen in the Barney Creek Formation, Glyde River Subbasin, DDH GR10; perpendicular to bedding.

- a) 443.0 m; bitumen veins, one vein appears to emanate from a slightly darker layer of calcilutite near the bottom of the photo, the layer is upraised at the point of expulsion; reflected white light, field-width = 8 mm;
- b) 443.0 m; same specimen as a); small silvery pieces of disseminated bitumen in central and peripheral areas of the photo; plane polarized reflected white light; scale bar = 30 microns; mean maxRo% = 0.52%;
- c) 443.0 m; same specimen as a); small grey centrally located piece of disseminated bitumen; plane polarized reflected white light; scale bar = 20 microns;
- d) as for c) but in fluorescence mode; note the central dark area which contains the single piece of disseminated bitumen, and bright yellow spots which are oil inclusions;
- e) 646.9 m; vein bitumen; plane polarized reflected white light; scale bar = 50 microns;
- f) as for e) but under crossed polarizers;
- g) 662.1 m; thin diagonal vein of bitumen; plane polarized reflected white light; scale bar = 20 microns; mean maxRo% = 0.90%.
- h) as for g) but in fluorescence mode; fluorescence appears most intense adjacent to the non-fluorescing bitumen vein;
- i) 662.1 m; centrally located bright-yellow fluorescing oil-filled vug just below the surface of the polished block.

PLATE 7

PLATE 8

**Thucholite and radiation-affected lamalginite, Barney
Creek Formation, Glyde River Subbasin, DDH GR10.**

PLATE 8

Thucholite and radiation-affected lamalginite, Barney Creek Formation, Glyde River Subbasin, DDH GR10; perpendicular to bedding.

- a) 23.2 m; large thucholite in plane polarized reflected white light; scale bar = 20 microns;
- b) as for a) but in fluorescence mode;
- c) 37.4 m; thucholite in plane polarized reflected white light; scale bar = 50 microns;
- d) as for c) but in fluorescence mode; note the thucholite has formed within a strand of lamalginite which is slightly displaced by the thucholite;
- e) 37.4 m; central white grain, probably zircon, partly surrounded by higher reflecting lamalginite, plane polarized reflected white light, scale bar = 20 microns;
- f) as for e) but in fluorescence mode, note partial loss of fluorescence in the lamalginite adjacent to the grain;
- g) 238.2 m; large thucholite grain in plane polarized reflected white light; scale bar = 30 microns;
- h) 392.4 m; centrally located small grey object is probably a sagittal section of a large thucholite; plane polarized reflected white light; scale bar = 20 microns;
- i) as for h) but in fluorescence mode;

PLATE 8

PLATE 9

**Fluorescent lamalginite, matrix and disseminated
bitumen, Barney Creek Formation, Glyde River Subbasin,
DDH's GR3 & 7.**

PLATE 9

**Fluorescent lamalginite, matrix and disseminated bitumen,
Barney Creek Formation, Glyde River Subbasin, DDH's GR3 & 7.
Perpendicular to bedding.**

a) DDH GR3, 302.6 m; low fluorescing lamalginite; scale bar = 50 microns;

b) as for a) but under reflected plane-polarized white light; note the somewhat dispersed nature of the silvery organic matter on the right side of the photo which has extremely low fluorescence and has been classified as disseminated bitumen; bitumen mean maxRo% = 0.40%.

c) and d) DDH GR3, 302.6 m; an example of a strand of lamalginite which at its right-hand end is much reduced in fluorescence and under white reflected light (d) appears disrupted; the irregular shaped silvery pieces on the right hand side of d) have been classified as disseminated bitumen; scale bar = 50 microns;

e) and f) DDH GR3, 302.6 m; low fluorescing organic matter which under white reflected light (f) has irregular shapes and in places surrounds mineral grains; classified as matrix and disseminated bitumen; scale bars = 50 microns;

g) GR7, 602.7 m; a thin discontinuous orange-yellow fluorescing strand of lamalginite and grains of carbonate showing bright yellow oil inclusions; scale is the same as h) where scale bar = 20 microns;

h) as for g) but in plane polarized white reflected light;

i) GR9, 79.1 m; wavy thin continuous strands of lamalginite, central circular area has been subjected to 3 hours of continuous UV excitation and shows marked positive alteration; scale bar = 50 microns.

PLATE 9

PLATE 10

Kerogen (fluorescent lamalginite) in strew mounts and SEM photographs of fluorescent lamalginite, Barney Creek Formation, Glyde River Subbasin, DDH GR10.

PLATE 10

Kerogen (fluorescent lamalginite) In strew mounts and SEM photographs of kerogen (fluorescent lamalginite), Barney Creek Formation, Glyde River Subbasin, DDH GR10.

a) 23.2 m; single large piece of kerogen in transmitted light; black patches are pyrite; scale bar = 20 microns;

b) as for a) but in fluorescence mode;

c) 23.2 m; as for a);

d) 51.8 m; part of a single large piece of kerogen displaying pseudocellular structure, transmitted light; scale bar = 20 microns;

e) 51.8 m; SEM of part of a kerogen piece showing plate-like structure; octahedron in lower part is pyrite;

f) 170.3 m SEM of part of a piece of kerogen also showing its plate-like structure.

PLATE 10

PLATE 11

A titaniferous bitumen nodule, containing possible filamentous microfossils; Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m; perpendicular to bedding.

PLATE 11

A titaniferous bitumen nodule, containing possible filamentous microfossils; Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m; perpendicular to bedding.

- a) titaniferous bitumen nodule containing pyritized branching filamentous structures which are possibly microfossils; plane-polarized light; scale bar = 20 microns;
- b) as for a) but in fluorescence mode;
- c) SEM image of same nodule as in a); scale bar = 20 microns;
- d) X-ray map of c) for Fe; same scale as for c);
- e) X-ray map of c) for S; same scale as for c);
- f) X-ray map of c) for Ti; same scale as for c);
- g) X-ray map of c) for Si; same scale as for c);
- h) X-ray map of c) for Ca; same scale as for c);
- i) X-ray map of c) for K; same scale as for c);
- h) X-ray map of c) for Ca; same scale as for c);
- i) X-ray map of c) for K; same scale as for c);
- j) X-ray map of c) for Al; same scale as for c).

PLATE 11

PLATE 12

A pyritic nodule containing oil inclusions, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m.

PLATE 12

A pyritic nodule containing oil inclusions, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m; perpendicular to bedding.

- a) a large pyritic nodule containing oil inclusions (X marks the location of three brown inclusions of oil); scale bar = 50 microns;
- b) as in a) but in fluorescence mode, oil in the nodule fluoresces a bright yellow;
- c) SEM image of a), slightly rotated, X marks the same oil inclusions as in a); scale bar = 50 microns;
- d) Higher power SEM image of area X; note cellular structure; scale bar = 10 microns;
- e) X-ray map of c) for Fe; scale bar = 50 microns;
- f) X-ray map of c) for S; scale bar = 50 microns.

PLATE 12

PLATE 13

**A titaniferous bitumen nodule, Barney Creek Formation,
Glyde River Subbasin, DDH GR10, 37.4 m.**

PLATE 13

A titaniferous bitumen nodule, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m, perpendicular to bedding.

- a) SEM showing a dark lobate bitumen nodule; scale bar = 50 microns;
- b) X-ray map for Fe of a), same scale as for a);
- c) X-ray map for S of a); same scale as for a);
- d) X-ray map for Ti of a); same scale as for a);
- e) X-ray map for Si of a); same scale as for a);
- f) X-ray map for Ca of a); same scale as for a);
- g) X-ray map for K of a); same scale as for a);
- h) X-ray map for Al of a); same scale as for a);
- i) X-ray map for Mg of a); same scale as for a).

PLATE 14

**A titaniferous bitumen nodule, Barney Creek Formation,
Glyde River Subbasin, DDH GR10, 37.4 m.**

PLATE 14

A titaniferous bitumen nodule, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m, perpendicular to bedding.

- a) large titaniferous bitumen nodule, bright spots are pyrite; plane-polarized white light; scale bar = 20 microns;
- b) as for a) but in fluorescence mode;
- c) SEM image of same nodule as in a); scale bar = 5 microns;
- d) X-ray map of c) for sulphur which appears to outline individual nodules that form the larger nodule; scale bar is 5 microns;
- e) X-ray map of c) for Fe; scale bar = 5 microns;
- f) X-ray map of c) for Ti; scale bar = 5 microns;
- g) X-ray map of c) for Si; scale bar = 5 microns;
- h) X-ray map of c) for Ca; scale bar = 5 microns;
- i) X-ray map of c) for K; scale bar = 5 microns.

PLATE 14

PLATE 15

SEM X-ray maps of a fluorescent lamalginite body and surrounding mineral matrix, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 92.6 m.

PLATE 15

SEM X-ray maps of a fluorescent lamalginite body and surrounding mineral matrix, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 92.6 m; perpendicular to bedding.

- a) SEM image showing a large lensoidal body of lamalginite (central black piece) and smaller lamalginite bodies (black) , scale bar = 0.1 mm;
- b) X-ray map of a) for Ca;
- c) X-ray map of a) for Fe;
- d) X-ray map of a) for S;
- e) X-ray map of a) for Si;
- f) X-ray map of a) for K;
- g) X-ray map of a) for Mg;
- h) X-ray map of a) for Al.

PLATE 15

PLATE 16

**SEM X-ray maps of a large mat of fluorescent
lamalginitite, Barney Creek Formation, Glyde River
Subbasin, DDH GR5, 72.5 m.**

PLATE 16

SEM X-ray maps of a large mat of fluorescent lamalginites, Barney Creek Formation, Glyde River Subbasin, DDH GR5, 72.5 m. Perpendicular to bedding.

- a) Central area shows a thick band of lamalginites under white reflected light, scale bar = 0.25 mm;
- b) as for a) but in fluorescence mode;
- c) SEM image of part of the thick band of lamalginites as shown in a) & b); scale bar = 0.25 mm;
- d) X-ray map of c) for Ca; same scale as for c);
- e) X-ray map of c) for Fe; same scale as for c);
- f) X-ray map of c) for S; same scale as for c);
- g) X-ray map of c) for Mg; same scale as for c);
- h) X-ray map of c) for Si; same scale as for c);
- i) X-ray map of c) for Al; same scale as for c);
- j) X-ray map of c) for K; same scale as for c).

PLATE 16

PLATE 17

**A scoured bed containing phosphate and fluorescent
lamalginite, Barney Creek Formation, Glyde River
Subbasin, DDH GR7, 180.0 m.**

PLATE 17

A scoured bed containing phosphate and fluorescent lamalglnite, Barney Creek Formation, Glyde River Subbasin, DDH GR7, 180.0 m; perpendicular to bedding.

1) A composite photo in white reflected light, showing a bed containing dark laminae of lamalglnite and phosphate that has been scoured on the right hand side; the brighter band overlying the phosphatic bed is pyrite rich; (a), (b), (c) & (d) refer to enlarged views of those areas shown in photos below which are all in fluorescence mode; scale bar = 1 mm;

a) Close-up of area (a) in (1); (p) refers to the dark non-fluorescing phosphate; field-width = 2.0 mm;

b) Close-up of area (b) in (1); (p) refers to the dark non-fluorescing phosphate; individual lamalglnite lamellae occur within the phosphate lens; field-width = 2.0 mm;

c) Close-up of area (c) in (1) at left-hand edge of the scour; (p) refers to the dark non-fluorescing phosphate; field-width = 2.0 mm;

d) Close-up of area (d) in (1) at the right-hand edge of the scour; (p) refers to the dark non-fluorescing phosphate; field-width = 2.0 mm;

PLATE 17

PLATE 18

**SEM images of the phosphate nodule shown in Plate 17a
from the Barney Creek Formation, Glyde River Subbasin,
DDH GR7, 180.0 m.**

PLATE 18

SEM Images of the phosphate nodule shown in Plate 17a from the Barney Creek Formation, Glyde River Subbasin, DDH GR7, 180.0 m; perpendicular to bedding.

a) SEM image of the phosphate nodule as shown on Plate 17a; scale bar = 0.1 mm;

b) SEM image of same nodule at a higher magnification; scale bar = 50 microns

c), d) and e) higher magnification SEM photos of the same nodule; scale bar in e) = 10 microns;

f) hexagonal crystals of phosphate from a lens of phosphate shown partly in Plate 17b; scale bar = 5 microns.

PLATE 19

**Phosphate laminae and nodule from the Barney Creek
Formation, Glyde River Subbasin, DDH GR7, 180.0 m.**

PLATE 19

Phosphate laminae and nodule from the Barney Creek Formation, Glyde River Subbasin, DDH GR7, 180.0 m.

- a) SEM image of phosphate nodule (central area) and lamina (as for Plate 17), bright double line separating the phosphatic-rich layer from the upper pyritic-rich bed is caused by a fissure produced during preparation of this specimen for X-ray mapping; scale bar = 1mm;
- b) X-ray map of a) at the same scale, for P;
- c) X-ray map of a) at the same scale, for Ca;
- d) X-ray map of a) at the same scale, for Si;
- e) X-ray map of a) at the same scale, for Fe;
- f) X-ray map of a) at the same scale, for S;
- g) X-ray map of a) at the same scale, for Al;
- h) X-ray map of a) at the same scale, for K;
- i) X-ray map of a) at the same scale, for Ti.

PLATE 19

PLATE 20

**Phosphate laminae and nodule from the Barney Creek
Formation, Glyde River Subbasin, DDH GR7, 180.0 m.**

PLATE 20

Phosphate laminae and nodule from the Barney Creek Formation, Glyde River Subbasin, DDH GR7, 180.0 m.

- a) X-ray map of lamalginite and phosphate laminae and nodule (as for Plate 17, but a different section to that used for Plate 18) for P;
- b) X-ray map of same area as in a) for Ca;
- c) X-ray map of phosphate lens (Plate 17b) for P; scale bar = 1mm;
- d) X-ray map of c) for Ca;
- e) X-ray map of right-hand side of scour (Plate17-1) for P;
- f) as for e) but for Ca;
- g) X-ray map of phosphate lens c) enlarged in area of detached laminae of lamalginite (Plate 17b), for P; scale bar = 20 microns;
- h) as for g) but for Ca; scale bar = 20 microns;
- i) as for g) but for Si; scale bar = 20 microns;
- j) as for g) but for Fe; scale bar = 20 microns;
- k) as for g) but for S; scale bar = 20 microns;
- l) as for g) but for Al; scale bar = 20 microns.

PLATE 20

PLATE 21

SEM X-ray maps of a thucholite grain, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m.

PLATE 21

SEM X-ray maps of a thucholite grain, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 37.4 m, perpendicular to bedding.

- a) SEM of a grain of thucholite, about 200 microns in diameter (round dark central area);
- b) X-ray map of a) for Fe; same scale as a);
- c) X-ray map of a) for S; same scale as a);
- d) X-ray map of a) for Si; same scale as a);
- e) X-ray map of a) for Ca; same scale as a);
- f) X-ray map of a) for K; same scale as a);
- g) X-ray map of a) for Ti; same scale as a);
- h) higher magnification X-ray map of central area of thucholite grain a) for Th; scale bar = 50 microns.

PLATE 21

PLATE 22

**SEM X-ray maps of a thucholite grain, Barney Creek
Formation, Glyde River Subbasin, DDH GR10, 297.2 m.**

PLATE 22

SEM X-ray maps of a thucholite grain, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 297.2 m, perpendicular to bedding; all at the same scale.

- a) SEM of a grain of thucholite; scale bar = 20 microns;
- b) X-ray map of a) for Fe;
- c) X-ray map of a) for S;
- d) X-ray map of a) for Si;
- e) X-ray map of a) for Ca;
- f) X-ray map of a) for K;
- g) X-ray map of a) for Mg;
- h) X-ray map of a) for Al;
- i) X-ray map of a) for Th.

PLATE 22

PLATE 23

SEM X-ray maps of a thucholite grain, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 297.2 m.

PLATE 23

SEM X-ray maps of a thucholite grain, Barney Creek Formation, Glyde River Subbasin, DDH GR10, 297.2 m, perpendicular to bedding; all at the same scale.

- a) SEM of a grain of thucholite; white scale bar at the top of the photo = 50 microns;
- b) X-ray map of a) for Fe;
- c) X-ray map of a) for S;
- d) X-ray map of a) for Si;
- e) X-ray map of a) for Ca;
- f) X-ray map of a) for K;
- g) X-ray map of a) for Al;
- h) X-ray map of a) for Mg.

PLATE 23

PLATE 24

**Organic matter from the Yalco and Lynott Formations,
central Batten Trough, McArthur Group.**

PLATE 24

Organic matter from the Yalco and Lynott Formations, central Batten Trough, McArthur Group; perpendicular to bedding.

- a) Yalco Formation, DDH 82/6, 125.5 m; fluorescent lamalginite disrupted by a sandstone dyke; fluorescence mode; field of view = 2.0 mm;
- b) Yalco Formation, DDH 82/6, 125.5 m; cross-bedded fluorescent lamalginite; fluorescence mode; field-width = 2.0 mm;
- c) Yalco Formation, DDH 82/6, 125.5 m; fluorescent lamalginite; fluorescence mode; scale bar = 50 microns;
- d) Lynott Formation, DDH 82/7, 327.5 m; large irregularly shaped bitumen in a bitumen-carbonate vein showing zones of lower reflectances; plane-polarised white reflected light; scale bar = 20 microns;
- e) as for d) but showing different zones of lower reflectances after stage has been rotated by 90 degrees;
- f) as for d) but under crossed polars;
- g) Reward Dolomite, DDH MY5, 67.2 m; an irregular grain of bitumen in a bitumen-carbonate vein; plane polarized white reflected light; field-width = 0.2 mm;
- h) as for g) but under crossed polars; note fine speckly green, red and yellow appearance;
- i) Lynott Formation, Leila Yard 1, 21.4 m; a thin vein of bitumen probably formed along a stylolite; plane polarized white reflected light; scale bar = 50 microns.

PLATE 24

PLATE 25

**Organic matter in the Barney Creek Formation and
Emmerugga, Teena and Reward Dolomites from the
central and northern parts of the Batten Trough.**

PLATE 25

Organic matter in the Barney Creek Formation and Emmerugga, Teena and Reward Dolomites from the central and northern parts of the Batten Trough; perpendicular to bedding.

- a) Barney Creek Formation, DDH CA1, 253.7 m; disseminated bitumen (arrows) and a patch of dispersed bitumen (circled) other white patches are mainly pyrite; mean maxRo = 1.90%; plane polarized reflected white light; field-width = 320 microns;
- b) Barney Creek Formation, DDH CA1, 337.6 m; thin strand of nonfluorescent lamalginite in central area; mean maxRo = 2.21%; plane-polarized reflected white light; field-width = 200 microns;
- c) Barney Creek Formation, DDH M17/08, 112.0 m; pyritized lamalginite (white strands in lower half of photo) with black strands of lamalginite (non-pyritised) in upper half of the photo; reflected white light; field-width = 0.8 mm;
- d) Barney Creek Formation, M17/08, 112.0 m; small piece of nonfluorescent lamalginite in central area; plane-polarized reflected white light; field-width = 200 microns;
- e) Barney Creek Formation, DDH BB2, 374.0 m; matrix bitumen in central area partially surrounding dark carbonate rhomb; mean maxRo% = 2.77; plane-polarized reflected white light; field-width = 200 microns.
- f) as for e) but under crossed polars;
- g) Reward Dolomite, DDH BB2, 72.0 m; a single rhombic piece of bitumen probably filling a vug; mean max.Ro% = 1.91; plane-polarized reflected white light; field-width = 200 microns.
- h) Emmerugga Dolomite, DDH McA10, 160.7 m; part of a bitumen-carbonate vein; mean maxRo% = 3.05; plane-polarized reflected white light; field-width = 320 microns;
- i) Teena Dolomite, DDH McA5, 446.4 m; part of a bitumen-pyrite vein, mean maxRo% = 1.83; plane- polarized reflected white light; field-width = 200 microns.

PLATE 26

Organic matter in the Cobanbarini Formation, "Lansen Creek Shale Member", Roper Group, Broadmere 1 well.

PLATE 26

Organic matter in the Cobanbarini Formation, "Lansen Creek Shale Member", Roper Group, Broadmere 1 well; perpendicular to bedding.

a) 27.4 m; dark strands of lamalginite; plane polarized white reflected light; scale bar = 20 microns;

b) as for a) but in fluorescence mode; both nonfluorescent and fluorescent lamalginite are present; a fluorescent strand is present in the upper right hand corner; mean maxRo for fluorescent lamalginite = 0.27%, for nonfluorescent lamalginite = 0.60%;

c) 109.7 m; a single discontinuous piece of nonfluorescent lamalginite; mean maxRo = 0.73%; plane polarized white reflected light; scale bar = 20 microns;

d) as for c) but in fluorescence mode;

e) 109.7 m; silvery disseminated and patchy dispersed bitumen showing rounded shapes of some of the bitumen (bitumen microspheres; lower left); plane-polarized white reflected light; scale bar = 20 microns;

f) as for e) but in fluorescence mode; fluorescing doughnut shapes are phosphate microspheres (see Plate 42 G-I), the rounded bitumen shapes adjacent to them do not fluoresce;

g) 335.3 m; nonfluorescent lamalginite and disseminated bitumen; plane polarized reflected white light; mean maxRo(lamalginite + bitumen) = 1.32%; scale bar = 20 microns;

h) as for g) but in fluorescence mode.

PLATE 27

**Organic matter in the lower Roper Group (Mainoru
Formation to Bessie Creek Sandstone), Broadmere 1
well.**

PLATE 27

Organic matter in the lower Roper Group (Mainoru Formation to Bessie Creek Sandstone), Broadmere 1 well; perpendicular to bedding.

- a) 466.3 m, Bessie Creek Sandstone; nonfluorescent lamalginite (central area); plane-polarised reflected white light; scale bar = 50 microns;
- b) as for a) but in fluorescence mode;
- c) 466.3 m Bessie Creek Sandstone; patchy dispersed silvery bitumen within black bitumen-impregnated patches and disseminated single bitumen pieces (one piece circled); plane polarized reflected white light; scale bar = 50 microns;
- d) as for c) but in fluorescence mode;
- e) 920.5 m, Corcoran Formation; slightly oblique section of nonfluorescent lamalginite in lower central area; plane-polarized reflected white light; scale bar = 20 microns;
- f) 1304.5 m, Hodgson Sandstone Member, Abner Sandstone; bitumen filling pore spaces; plane-polarized reflected white light; scale bar = 50 microns;
- g) 2075.7 m, Mainoru Formation; nonfluorescent lamalginite (circled); plane polarized reflected white light; scale bar = 20 microns;
- h) 2106.2 m, Mainoru Formation; nonfluorescent lamalginite in central upper half of the photo; plane polarized reflected white light; scale bar = 20 microns;
- i) 2170.2 m, Mainoru Formation; part of a vein of carbonate (light grey to white patches, one marked "c") and bitumen (small speckly silvery shapes) within a quartz arenite (light grey shapes, one marked "q"), dark area at top is resin; plane polarized reflected white light; scale bar = 20 microns.

PLATE 27

PLATE 28

**Organic matter in the Velkerri Formation, Maiwok
Subgroup, Roper Group, DDH Urapunga 3.**

PLATE 28

Organic matter in the Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urapunga 3; perpendicular to bedding.

- a) 30.3 m; laminated silty mudstone, darker laminae are organic rich and contain lamalginite; reflected white light; field-width = 8 mm;
- b) 30.3 m; fluorescent and nonfluorescent lamalginite; a strand of fluorescent lamalginite occurs in the upper central area; carbonate rhomb in lower left contains bright yellow oil inclusions; fluorescence mode; field-width = 200 microns.
- c) as for b) but under plane-polarized white reflected light; mean maxRo for fluorescent lamalginite = 0.30%, for nonfluorescent lamalginite = 0.66%;
- d) 54.4 m; vein bitumen, plane-polarized white reflected light; mean maxRo = 0.79%; scale bar = 20 microns;
- e) 54.4 m; edge of a large vein of bitumen showing a thin vein of bitumen parallel to bedding or nonfluorescent lamalginite joining it; plane-polarized white reflected light; field-width = 200 microns;
- f) 54.3 m; discontinuous piece of nonfluorescent lamalginite or possibly a conformable veinlet of bitumen, plane-polarized white reflected light; field-width = 200 microns;
- g) 75.2 m; centrally located patch of carbonate (grey) and associated irregularly shaped silvery grains of bitumen (patchy dispersed bitumen); white grains are pyrite; mean maxRo = 1.01%; plane-polarized white reflected light; scale bar = 10 microns;
- h) 75.2 m; centrally located patch of carbonate and irregularly shaped grains of silvery bitumen associated with it (patchy dispersed bitumen); plane polarized white reflected light; scale bar = 10 microns;
- i) 98.3; matrix bitumen surrounding carbonate rhombs; mean maxRo = 1.69%; plane polarized white reflected light; field-width = 0.20 mm;

PLATE 28

PLATE 29

**Vein bitumen, Velkerri Formation, Maiwok Subgroup,
Roper Group, DDH Urupunga 3, 98.3 m.**

PLATE 29

Vein bitumen, Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urupunga 3, 98.3 m; perpendicular to bedding.

a) vein of cross-cutting and conformable bitumen and carbonate which flowed into the lower darker organic-rich bed containing matrix bitumen (Plate 28i); reflected white light; field-width = 3.4 mm.

b) same vein as a) but a mirror image at a higher magnification, in the area where the vein changes from being conformable to cross-cutting; plane-polarized white reflected light; mean maxRo = 1.69%; scale bar = 50 microns;

c) same as b) but under crossed polars; approximately parallel black lines and irregularly shaped black areas in the bitumen indicate zones where lamina and turbulent flow of the bitumen took place; the lamina flow of the bitumen appears disturbed by a small carbonate rhomb trapped within the vein in the central area of the microphotograph indicating the flow of the bitumen is from left to right, i.e. into the darker organic-rich bed shown in Plate 29a.

d) bitumen (b) and carbonate (c) in conformable part of the same vein as a); plane-polarized white reflected light; field-width = 200 microns;

e) as for d) but under crossed polars showing conformable and parallel, black and white, low to highly bireflectant, bands of bitumen indicating that lamina flow of the bitumen took place at one time;

f) part of the same vein as for d) but cross-cutting the bedding; plane-polarized white reflected light; field-width = 200 microns;

g) as for f) but under crossed polars showing irregularly shaped areas of black and white, low to highly bireflectant zones of bitumen within the vein indicating that non-lamina, or turbulent, flow took place at one time;

h) conformable part of the same vein as for d); the letter "b" marks the bitumen and "c" the carbonate in the vein; plane-polarized white reflected light;

i) as for h) but in fluorescence mode showing oil inclusions (diffuse white shapes) in the carbonate and lack of fluorescence in the bitumen; scale bar = 20 microns.

PLATE 30

Carbonate and pyrite pseudomorphs after gypsum, and organic matter in the Velkerri Formation, Maiwok Subgroup, Roper Group, DDH Urapunga 3, 120.0 to 150.1 m.

PLATE 30

Carbonate and pyrite pseudomorphs after gypsum, and organic matter in the Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urupunga 3, 120.0 to 150.1 m; perpendicular to bedding.

a) 120.0 m; centrally located single piece of cauliflower bitumen; plane-polarized white reflected light, scale bar = 20 microns;

b) as for a) but in fluorescence mode;

c) 120.0 m; a large single piece of cauliflower bitumen displaying variable bireflectance; plane-polarized white reflected light, scale bar = 30 microns;

d) a centrally located disrupted strand of silvery nonfluorescent lamalginite containing imbedded grey microspheres of phosphate; plane polarized white reflected light, scale bar = 20 microns;

e) 130.0 m; randomly orientated discoidal shapes that are mostly carbonate but the one on the lower right is pyrite (bright white shape), which are probably pseudomorphous after gypsum; plane-polarized white reflected light, scale bar = 50 microns;

f) 137.4 m; a centrally located, cauliflower bitumen piece, and peripheral smaller silvery bitumen pieces; plane-polarized white reflected light, scale bar = 50 microns;

g) 150.1 m; vein bitumen and pieces of nonfluorescent lamalginite; white reflected light; field-width = 8 mm;

h) 150.1 m; an isolated piece of nonfluorescent lamalginite; mean maxRo% = 2.10; plane polarized white reflected light, scale bar = 20 microns;

i) as for h) but in fluorescence mode.

PLATE 31

**Organic matter in the Velkerri Formation, Maiwok
Subgroup, Roper Group, DDH Urapunga 3, 150.1 to
210.7 m.**

PLATE 31

Organic matter in the Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urapunga 3; perpendicular to bedding.

- a) 150.1 m, vein bitumen; plane-polarized white reflected light, scale bar = 20 microns;
- b) as for a) but under crossed polars;
- c) 172.6 m; randomly orientated pieces of nonfluorescent lamalginite, white reflected light; mean maxRo = 2.34%; field width = 3.4 mm;
- d) 172.6 m; isolated piece of nonfluorescent lamalginite; plane-polarized white reflected light, scale bar = 20 microns;
- e) 172.6 m; several strands of nonfluorescent lamalginite; plane-polarized white reflected light; field-width = 200 microns;
- f) 210.7 m; nonfluorescent lamalginite of varying sizes and differing orientations due to soft-sediment movement; white reflected light; mean maxRo = 3.41%; field-width = 8 mm;
- g) 210.7 m; pieces of nonfluorescent lamalginite, some contorted due to soft sediment movement; white reflected light; field-width = 3.4 mm;
- h) 210.7 m; two small pieces of lamalginite, one showing silvery reflecting surface; plane polarized white reflected light, scale bar = 50 microns;
- i) as for h) but in fluorescence mode showing faint mineral fluorescence but no lamalginite fluorescence.

PLATE 31

PLATE 32

**Oncolites, McMinn Formation, Maiwok Subgroup, Roper
Group; DDH Urapunga 4, 32.3m.**

PLATE 32

Oncolites, McMinn Formation, Maiwok Subgroup, Roper Group; DDH Urapunga 4, 32.3m; perpendicular to bedding.

A) A composite photo showing a variety of oncolite shapes, from spheroidal in the central area to lenticular in upper and lower areas. A broken spheroidal oncolite is in an arenite bed in upper half of the photo; white reflected light;

B) a large lenticular oncolite, in the upper half of the photo, that has a nucleus of several mineral grains whereas underlying oncolite has no obvious nucleus and appears partly deformed around an underlying quartz grain; white reflected light; field-width = 3.4 mm;

C) a fluted oncolite, in the central area; the black "tail" of this oncolite is typical of the dark, thin, lenticular oncolites forming much of the lower half in photo A; white reflected light; field-width = 3.4 mm;

D) lenticular oncolites; white reflected light; field-width = 3.4 mm.

5mm

PLATE 33

**Oncalginite and bitumen, McMinn Formation, Maiwok
Subgroup, Roper Group, DDH Urapunga 4, 32.3 m.**

PLATE 33

Oncalginite and bitumen, McMinn Formation, Malwok Subgroup, Roper Group, DDH Urapunga 4, 32.3 m. Perpendicular to bedding.

A) Thin silvery laminae of oncalginite diverging and passing around a round quartz grain on the left which forms the nucleus of a lenticular oncolite; plane-polarized white reflected light; scale bar = 50 microns;

B) thin silvery laminae of oncalginite; plane-polarized white reflected light; scale bar = 50 microns;

C) matrix bitumen in centre partially surrounding a darker carbonate rhomb, and oncalginite or vein bitumen on the right; plane-polarized white reflected light; mean maxRo (oncalginite + bitumen) = 1.54%; scale bar = 50 microns;

D) part of a large spherical oncolite showing darker, probably organic rich laminae surrounding a rounded quartz grain nucleus on the right; plane-polarized white reflected light; field-width = 300 microns;

E) single strands of thin silvery oncalginite; plane polarized white reflected light; scale bar = 50 microns;

F) as for E) but under crossed polars;

G) a single thin wavy silvery strand of oncalginite following the laminae of a lenticular oncolite; plane polarized white reflected light; field-width = 300 microns;

H) two parallel thin silvery oncalginite strands which diverge and partially pass around a lens of sphalerite on the left; plane polarized white reflected light; field-width = 300 microns;

I) as for H) but under crossed-polars demonstrating the strong anisotropism of the sphalerite and the lack of anisotropism of the oncalginite.

PLATE 33

PLATE 34

**Organic matter in the Velkerri Formation, Maiwok
Subgroup, Roper Group, DDH Urapunga 4; 157.3 to 209.5
m.**

PLATE 34

Organic matter in the Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urupunga 4; 157.3 to 209.5 m; perpendicular to bedding.

A) 157.3 m; a strand of fluorescent lamalginite in the central area; white blurry spots are pyrite; plane-polarized reflected white light; mean maxRo (fluorescent lamalginite) = 0.28%; scale bar = 20 microns;

B) as for A) but in fluorescence mode, the lamalginite strand is weakly fluorescent;

C) 157.3 m; an isolated piece of nonfluorescent lamalginite in central area; white blurry spots are pyrite; plane polarized reflected white light; mean maxRo (nonfluorescent lamalginite) = 0.50%; scale bar = 20 microns;

D) as for C) but in fluorescence mode;

E) 209.5 m; a light-grey strand of nonfluorescent lamalginite in the central upper area of the photo and a strand of dark-grey fluorescent lamalginite in the lower half of the photo; white blurry spots are pyrite; mean maxRo (fluorescent lamalginite) = 0.29%, mean maxRo (nonfluorescent lamalginite) = 0.59%; plane polarized reflected white light; scale bar = 20 microns;

F) as for E) but in fluorescence mode;

G) 209.5 m, a silvery, broken-up, strand of nonfluorescent lamalginite in the upper half of the photo and irregularly shaped bitumen with imbedded phosphate microspheres in the lower left of the photo; white blurry spots are pyrite; plane polarized reflected white light; scale bar = 20 microns;

H) as for G) but in fluorescence mode, phosphate microspheres have fluorescent rims;

I) 209.5 m; a lens of carbonate in the central right area of the photo containing bright yellow fluorescent oil inclusions; scale bar = 20 microns.

PLATE 34

PLATE 35

Organic matter in the Velkerri Formation, Maiwok Subgroup, Roper Group, DDH Urapunga 4; 258.5 to 348.2 m.

PLATE 35

Organic matter in the Velkerri Formation, Malwok Subgroup, Roper Group, DDH Urapunga 4; 258.5 to 348.2 m; perpendicular to bedding.

A) 258.5 m; isolated black pieces of lamalginite, different orientations of the lamalginite probably due to soft sediment slumping of the mudstone; white reflected light; field-width = 8 mm;

B) 258.5 m; an isolated strand of lamalginite; plane-polarized white reflected light; scale bar = 30 microns;

C) as for B) but in fluorescence mode; lamalginite is faintly fluorescent in places;

D) 342.7 m; a strand of nonfluorescent lamalginite in the lower half of the photo and pieces of disseminated bitumen (circled); plane-polarized white reflected light; mean maxRo(nonfluorescent lamalginite) = 0.98%; scale bar = 50 microns;

E) 342.7 m, part of a vuggy band of lutite containing oil; a small vug appears as a blurry white object in the center of the photo; plane-polarized white reflected light; scale bar = 20 microns;

F) as for E) but in fluorescence mode showing brightly fluorescing oil; free oil was observed bubbling from this core over the interval 345.4 - 346.55 m (Jackson et al., 1987);

G) an originally non-fluorescing greywacke that has had a drop of oil from Urapunga 4 placed on it; the oil has impregnated the mineral matrix and has produced similar effects as seen in fluorescing mineral matrices in a number of specimens observed from the the McArthur Basin; fluorescence mode; field-width = 0.8 mm;

H) 347.0 m; a brightly fluorescing diagonal fissure containing oil surrounded by patches of fluorescing mineral matter; fluorescence mode; field-width = 0.8 mm;

I) 348.2 m; a broken-up strand of nonfluorescent lamalginite in the central area of the photo; plane-polarized white light; mean maxRo(nonfluorescent lamalginite) = 1.05%; scale bar = 50 microns.

PLATE 36

**Organic matter in the Velkerri and Corcoran Formations,
Roper Group, DDH Urapunga 4; 354.7 to 463.8m.**

PLATE 36

Organic matter in the Velkerri and Corcoran Formations, Roper Group, DDH Urapunga 4; 354.7 to 463.8 m; perpendicular to bedding.

A) 354.7 m; Velkerri Formation; nonfluorescent lamalginite (long thin silvery strand in the central area of the photo, white spots are pyrite); plane-polarized white reflected light; mean maxRo(nonfluorescent lamalginite) = 1.09%; scale bar = 20 microns;

B) as for A) but in fluorescence mode;

C) 354.7 m; Velkerri Formation; dispersed bitumen (light grey colour, a large piece is at left central area of photo, white spots are pyrite); plane-polarized white reflected light; scale bar = 20 microns;

D) as for C) but in fluorescence mode;

E) 463.8 m, Corcoran Formation; dark laminae are organic matter; buckled appearance of one laminae in the central area indicates soft-sediment slumping; white reflected light; field-width = 8 mm;

F) 463.8, Corcoran Formation; a silvery piece of disseminated bitumen in the central area of the photo; the dark bands are bitumen-impregnated mineral matter; plane-polarized white reflected light; mean maxRo(nonfluorescent lamalginite + bitumen) = 1.42%; scale bar = 20 microns;

G) as for F) but in fluorescence mode; the piece of disseminated bitumen and the bitumen-impregnated mineral matter is not fluorescent but mineral matter that is not bitumen-impregnated is strongly fluorescent;

H) 463.8, Corcoran Formation; nonfluorescent lamalginite and nonfluorescing bitumen-impregnated mineral matter and strongly fluorescing mineral matter; fluorescence mode; scale bar = 20 microns;

I) as for H) but in plane-polarized white reflected light mode.

PLATE 36

PLATE 37

**Organic matter in the McMinn Formation, Maiwok
Subgroup, Roper group, DDH X28.**

PLATE 37

Organic matter in the McMinn Formation, Malwok Subgroup, Roper group, DDH X28; perpendicular to bedding.

A) 16.9 m; a composite photo of a single large fluorescent lamalginitic body and smaller fluorescent lamalginitic; plane-polarised reflected white light; mean maxRo(fluorescent lamalginitic) = 0.20%; scale bar = 50 microns;

B) as for A) but in fluorescence mode;

C) 16.9 m; a large lamalginitic body composed of a number of lamellae, and smaller lamalginitic bodies; fluorescence mode; scale bar = 50 microns;

D) 32.0 m; discontinuous lamalginitic bodies of varying sizes; fluorescence mode; field-width = 0.8 mm;

E) 61.0 m; long thin lamalginitic bodies; fluorescence mode; field-width = 2.0 mm;

F) 82.9 m; a small discrete lamalginitic body; plane-polarized reflected; mean maxRo(fluorescent lamalginitic) = 0.40%; white light; scale bar = 50 microns;

G) as for F) but in fluorescence mode, lamalginitic shows faint fluorescence while surrounding mineral matter is strongly fluorescent.

PLATE 37

PLATE 38

Thucholite grains in the Roper Group.

PLATE 38

Thucholite grains in the Roper Group; perpendicular to bedding.

- a) McMinn Formation, DDH X28, 16.9 m, plane-polarised white reflected light; scale bar = 50 microns,
- b) as for a) but under crossed polars;
- c) as for a) but in fluorescence mode;
- d) McMinn Formation, DDH X28, 32.0 m, showing thucholitic bitumen formed around a presumably radioactive section in a grain of mica; plane-polarised white light; scale bar = 20 microns,
- e) as for d) but in fluorescence mode;
- f) McMinn Formation, DDH X28, 32.0 m, lamalginite appears displaced by the grain of thucholite which has a fluorescent halo; fluorescence mode; field width = 0.8 mm;
- g) Velkerri Formation, DDH Urapunga 4, 342.7 m, plane-polarized white reflected light, field width = 0.2 mm,
- h) Velkerri Formation, DDH Urapunga 4, 354.7 m, thucholite, plane-polarized reflected white light; scale bar = 20 microns,
- i) as for h) but in fluorescence mode; the thucholite has a large fluorescent halo due to it being almost a tangential section of a larger grain.

PLATE 39

Possible pseudomorphs after gypsum in the Velkerri Formation and organic matter in the Velkerri Formation, Abner Sandstone & Mainoru Formation in DDH's 82/1,2,3 & 8.

PLATE 39

Probable pseudomorphs after gypsum in the Velkerri Formation and organic matter in the Velkerri Formation, Abner Sandstone & Mainoru Formation in DDH's 82/1,2,3 & 8; perpendicular to bedding.

A) DDH 82/1, 380.6 m, Velkerri Formation, showing small grains of dark carbonate and light grey pyrite which are probably pseudomorphous after gypsum, in mudstone; white reflected light; field-width = 8 mm;

B) as for A) but at an higher magnification showing a rosette of pyrite and carbonate which is probably pseudomorphous after gypsum.

C) DDH 82/1, 380.6 m; Velkerri Formation; showing part of a relatively large body of fluorescent lamalginite containing pyrite (white spots); mean maxRo% = 0.47; plane polarized white reflected light; scale bar = 20 microns;

D) as for C) but in fluorescence mode;

E) DDH 82/8, 67.4 m, Velkerri Formation, showing an discrete body of fluorescent lamalginite; mean maxRo%(fluorescent lamalginite) = 0.32; plane-polarized white reflected light; scale bar = 50 microns;

F) DDH 82/3, 145.3 m, Jalboi Member, Abner Sandstone, showing a discrete body of nonfluorescent lamalginite; mean maxRo% = 2.39; plane-polarized white reflected light; field-width = 0.20 mm;

G) DDH 82/2, 66.8 m, Mainoru Formation, showing sandy and silty bands containing discrete bodies of lamalginite; white reflected light; field-width = 3.4 mm;

H) as for G) but at an higher magnification showing a single discrete piece of nonfluorescent lamalginite; mean maxRo% = 2.21; plane polarized white reflected light; scale bar = 20 microns;

I) DDH 82/3 478.5 m, Mainoru Formation; plane polarized white reflected light; showing a discrete body of nonfluorescent lamalginite; mean maxRo% = 2.01; scale bar = 20 microns.

PLATE 40

**Organic matter in the Abner Sandstone and Mainoru
Formation, Roper Group; DDH's Urapunga 1 & 5.**

PLATE 40

Abner Sandstone and Mainoru Formation, Roper Group; DDH's Urapunga 1 & 5; perpendicular to bedding.

A) Mainoru Formation, Urapunga 1, 120.9 m; a discrete piece of nonfluorescent lamalginite; mean maxRo% = 2.67; plane-polarized white reflected light; scale bar = 20 microns;

B) Jalboi Member, Abner Sandstone, Urapunga 5, 140.0 m; several pieces of nonfluorescent lamalginite; mean maxRo% = 4.25; plane-polarized white reflected light; field-width = 200 microns;

C) Jalboi Member, Abner Sandstone, Urapunga 5, 148.9 m, composite photo showing a coarse arenite bed and organic rich lutites; white reflected light; scale bar = 1 mm;

D) Arnold member, Abner Sandstone, Urapunga 5, 323.5 m; small discrete piece of nonfluorescent lamalginite, mean maxRo% = 4.27; plane-polarized white reflected light; scale bar = 20 microns;

E) Mainoru Formation, Urapunga 5, 590.1 m; large rectangular piece of bitumen, probably vug bitumen, in the central area of the photo; mean maxRo% = 2.31; plane-polarized white reflected light; scale bar = 20 microns;

F) as for E) but under crossed-polars, showing speckled appearance of the bitumen;

G) Mainoru Formation, Urapunga 5, 590.1 m; showing a patch irregularly shaped pieces of bitumen (circled);

H) as for G) but under crossed-polars.

PLATE 41

**SEM X-ray maps of bitumen veins in the Velkerri
Formation, DDH Urapunga 3, 98.3 m.**

PLATE 41

SEM X-ray maps of bitumen veins in the Velkerri Formation, DDH Urupunga 3, 98.3 m; all at the same scale; perpendicular to bedding.

- A) X-ray map for Si; large continuous dark area is a bitumen vein (see also Plate 29 for photomicrographs of this vein);
- B) X-ray map for calcium of A);
- C) X-ray map for phosphorus of A);
- D) SEM photo of conformable and cross-cutting bitumen veins;
- E) X-ray map for silica of D);
- F) X-ray map for calcium of D);
- G) X-ray map for potassium of D);
- H) X-ray map for aluminium of D);
- I) X-ray map for phosphorus of D).

PLATE 41

PLATE 42

**SEM images and X-ray maps of phosphates in the Roper
Group.**

PLATE 42**SEM Images and X-ray maps of phosphates in the Roper Group;
perpendicular to bedding.**

- A) Velkerri Formation, DDH Urapunga 3 at 49.8 m; SEM photo showing central dark area of lamalginite with an imbedded microsphere of phosphate;
- B) X-ray map for calcium of A);
- C) X-ray map for phosphorus of A);
- D) Velkerri Formation, DDH Urapunga 4, 157.3 m; showing dark organic matter and doughnut-shaped phosphate microspheres;
- E) X-ray map for calcium of D);
- F) X-ray map for phosphorus of D);
- G) Cobanbirini Formation, Broadmere 1 well, 109.7 m; SEM photo showing doughnut shaped phosphate microspheres;
- H) X-ray map for calcium of G);
- I) X-ray map for phosphorus of G).

PLATE 42