

365001

PALYNOLOGIC, SOURCE ROCK AND UTRINITE REFLECTANCE STUDIES

DURROON NO. 1

D of M	A.O.	C.G.	E.O.	D.S.M.E.
				Registrar
D. DIR.	10 FEB 1986			E & IL
	DEPT. OF MINES			
REF. No.	1,226			86

Bridge Oil Limited,  
December 1985,  
521/101/HH.

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## 1. INTRODUCTION

The following studies have been carried out to further evaluate the hydrocarbon potential of permits T-15-P and T-16-P.

- Palynologic studies on cuttings from Durroon No. 1 well over the interval 4,330' - 6,490' in order to have a better understanding of (1) the location of two major unconformities in the stratigraphic section and, (2) the magnitude of the resultant hiatuses. The study was performed by Roger Morgan as subcontractor for Analabs, Perth.
- Geochemical studies on cuttings from Durroon No. 1 well over the interval 4,540' - 6,490' to test the source potential of (1) shales interpreted to interfinger with alluvial-fan sandstones downdip of the Durroon well and, (2) the top of the Otway Group. Work was performed by Analabs, Perth.
- Vitrinite reflectance studies on cuttings from Durroon No. 1 well over the interval 4,540' - 5,020' to assess maturation levels. Work was subcontracted by Analabs to Keiraville Konsultants.

## 2. CONCLUSIONS

The Top-Lower Cretaceous unconformity has been clearly defined by a major hiatus (approx. 8 million years).

The Mid-Upper Cretaceous unconformity is expressed by a larger hiatus than was previously recognised (approx. 15 million years).

In Durroon No. 1, the interval between forementioned unconformities is entirely of C.triplex age. This shale interval is thought to interfinger downdip with the deepest mapped alluvial fan (Lower Fan).

The C.triplex Zone in Durroon No. 1 represents a poor oil source rock but could be a moderate to good gas source rock. Although TOC values are good, pyrolysis yields are very low. Due to the position of Durroon No. 1 on the upthrown side of a rotated fault block, better preserved and richer source material is likely to be present downdip from the well in the fault trough to later source the "C.triplex fan" with hydrocarbons.

Visual kerogen analysis indicated that the top of the Otway Group (upper C.paradoxa Zone) could constitute a good oil-prone source rock. However, subsequent Rock Eval tests on three samples again indicated low pyrolysis yields.

Maturity levels as indicated by vitrinite reflectance data are higher than previously believed. It is very likely the oil-generating zone is reached by the bit in tests of less than 9000 feet.

However, additional vitrinite reflectance determinations are needed to locate the top of the oil-generative zone more clearly.

### 3. PALYNOLOGIC STUDIES

A total of ten samples, over the interval 4,330' - 6,490' were studied (Attachment 1 and Enclosure 1).

Main conclusions are :

- (a) N.senectus and T.pachuexinus Zones are not seen in the samples and the resultant stratigraphic hiatus is in the order of 15 million years, (Figure 1). Previously it was believed that the top of the N.senectus Zone was represented in the well. The "Mid-Upper Cretaceous Unconformity", an important seismic marker, remains at 4,492'K.B. and its position in the well was not affected.
- (b) A.distocarinatus and T.pannosus Zones are not seen in the samples. Previously it was thought that both zones were represented in the well. It has now been established that the "Top-Lower Cretaceous Unconformity", an important seismic horizon, represents an hiatus of about 8 million years at the Durroon No. 1 location, (Figure 1). The position of this unconformity within the well has not changed and remains at 5,566'K.B.
- (c) It has been established that the volcanics in Durroon No. 1 lie within the C.triplex Zone of the Late Cretaceous and should not be directly correlated with volcanics from the Cape Portland area which have an absolute age dating of 101 -102 Ma, and are as such about 10 million years older (Figure 1).
- (d) Environment of deposition during C.triplex and upper C.paradoxa Zone time was predominantly non-marine, with occasionally marine influences as indicated by rare acritarchs.

- (e) Visual analysis of kerogen on four samples within the upper C.paradoxa Zone indicates oil-prone source rock with liptinite contributing 50% of the kerogen. The C.triplex Zone indicated oil prone source rock only at its base and good gas/condensate-prone source rock over the remainder of the zone.

#### 4. GEOCHEMICAL STUDIES

A total of 14 samples, over the interval 4,540'-6,490', have been analysed to determine the source potential and thermal maturity of this interval (Attachment 2, Enclosure 1).

The main conclusions are :

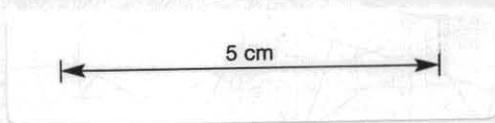
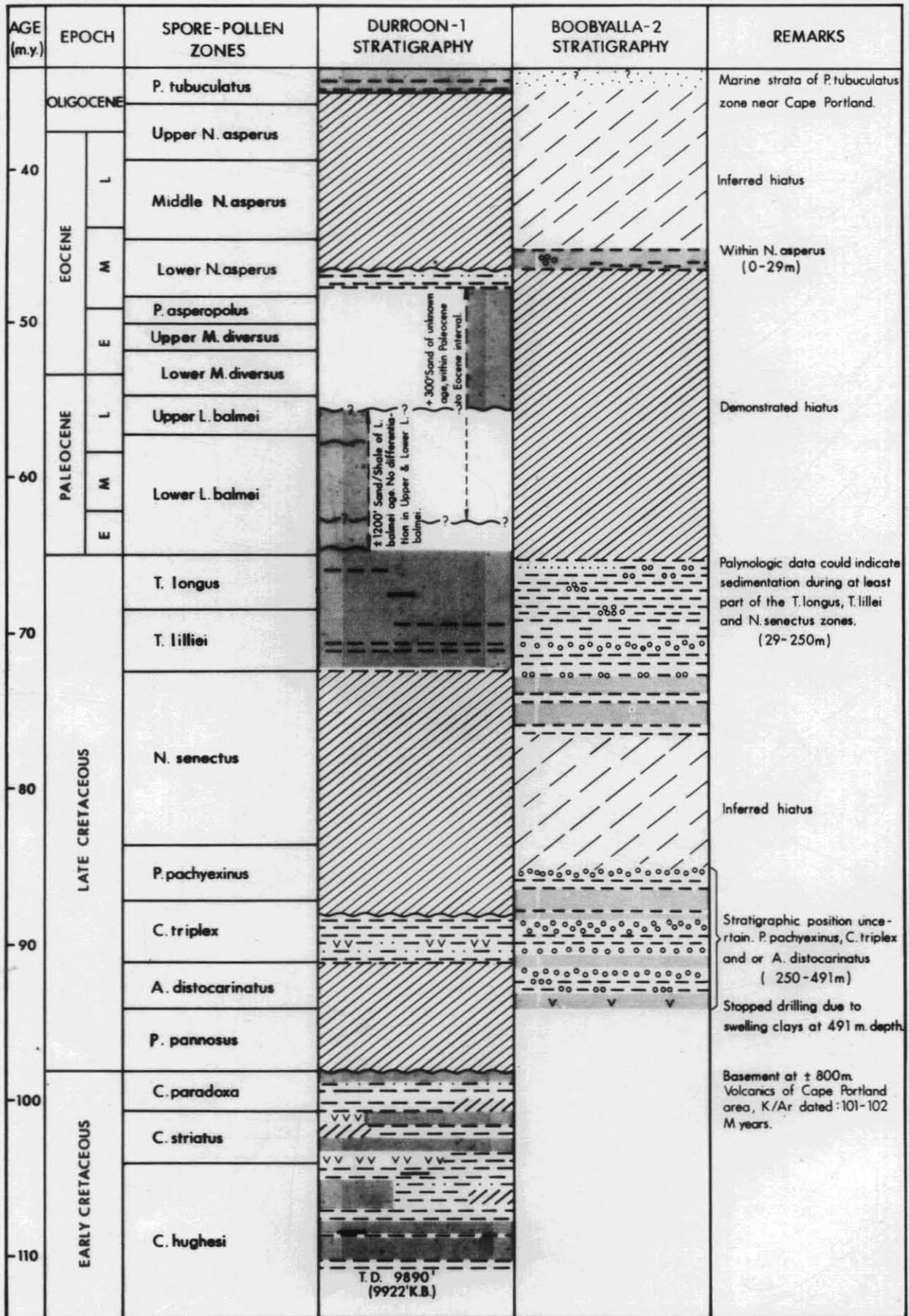
- (a) The sediments over this interval have good TOC content, with TOC values ranging from 1.26-1.80% over 12 samples. The value of 0.92% TOC from a sample at 4540' has been discarded due to its proximity to the "Mid Upper Cretaceous Unconformity". The sample of 6,490' gave a TOC content of 0.37. As Durroon No. 1 was the only well in the Bass Basin to intersect the C.triplex Zone, the data can only be compared to younger strata (Table 1).
- (b) Samples produced low pyrolysis yields. Analabs concluded - 'The organic matter is dominated by inertinite and vitrinite, which are normally considered to be gas prone. In addition, iron oxides are abundant which suggest the organic matter may be poorly preserved. As a result, the rocks have very limited oil-generating capability, but may have moderate to good gas source potential at optimum maturity.'
- (c) It is considered that the ill-preserved state of the organic matter at the Durroon No. 1 location is due to its position on the upthrown side of a rotated fault block, a position that would invoke periods of no deposition, oxidation or erosion and low sedimentation rates. Strata of C.triplex age are seen on seismic to on lap the "Durroon High". It is concluded that source rock parameters are likely to be more favourable for the sediments in the rapidly subsiding fault graben.
- (d) The TMAX temperatures (Rock Eval) range from 434° to 436°C and indicate that the sediments over the studied interval are marginally/moderately mature for oil generation (Sec. 4).

## 5. VITRINITE REFLECTANCE STUDIES

The rocks analysed between 4,540' and 5,020' are marginally mature for oil generation as evidenced by vitrinite reflectance values of 0.54 to 0.58% Ro. Analabs concluded : 'At these low levels of alteration, the rocks are in the initial stages of petroleum generation. It is doubtful that these sediments could have generated significant amounts of petroleum'.

It is encouraging however, that the recent vitrinite values indicate a more intense geothermal history than previously believed (Figure 2).

\* \* \* \* \*

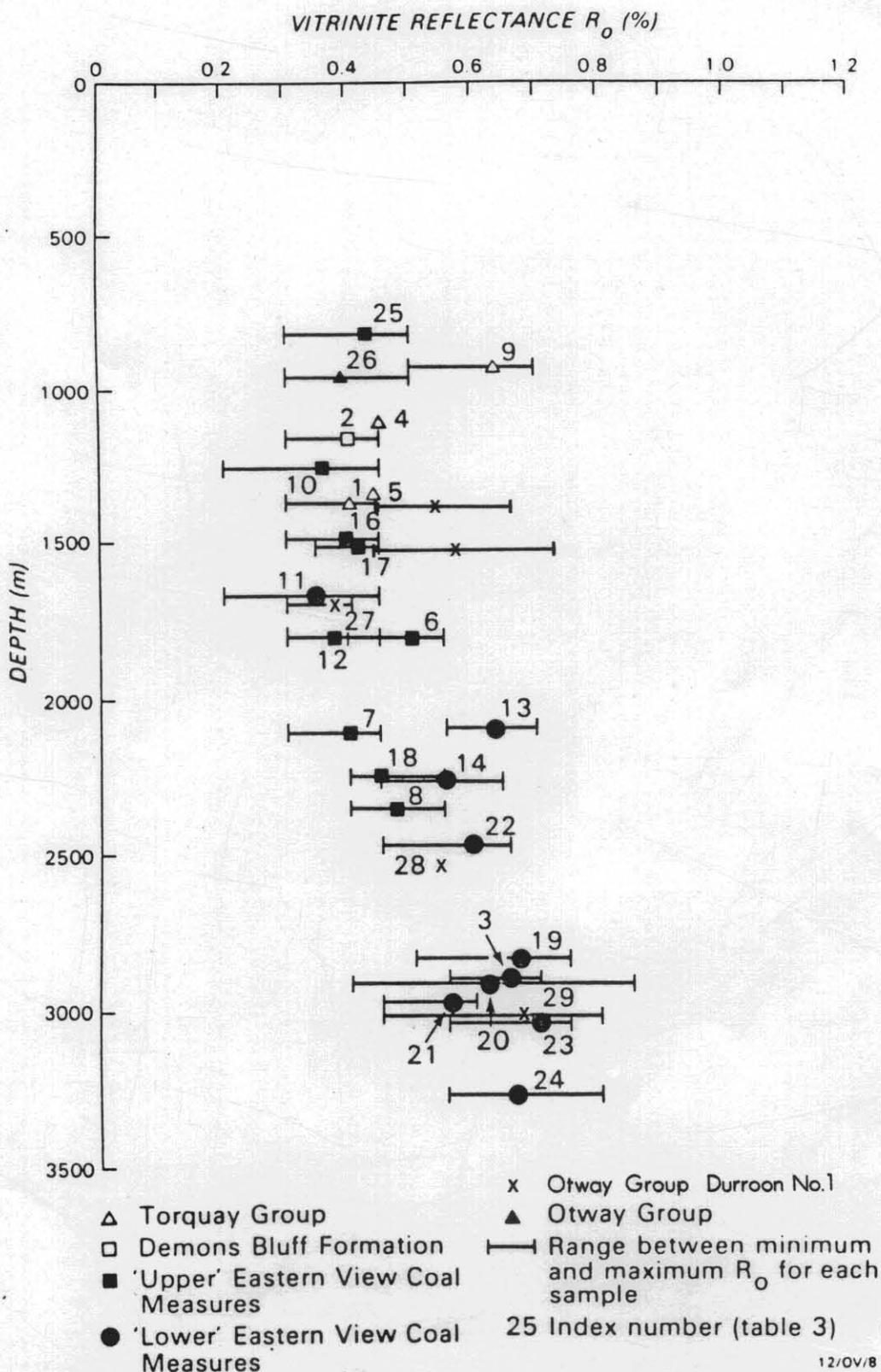


**B BRIDGE OIL LTD**

**DURROON-1  
VERSUS  
BOOBYALLA-2  
STRATIGRAPHY**

AUTHOR: H.H.    DATE: AUGUST '85    FIG. N° :    |

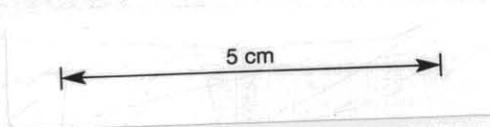
Revised: Dec '85



**Figure 2 Vitrinite reflectance plotted against depth in Bass Basin.**

Data without range bars have too few determinations to give a reliable mean.

(After E.Nicholas, K.L.Lockwood, A.R.Martin<sup>1</sup>, & K.S.Jackson)



Well name	Unit	Core No.	Total organic carbon (TOC) (%)	Oil & gas content $S_1$ (mg hydrocarbon/g rock)	Petroleum potential $S_1+S_2$ (mg hydrocarbon/g rock)	Production index $S_1/(S_1+S_2)$	Hydrogen index $S_2/TOC$ (mg hydrocarbon/g TOC)	Oxygen index $S_3/TOC$ (mg $CO_2/g$ TOC)	Hydrogen: oxygen ratio (H/O)
Bass No. 3	Torquay Gp	4	1.30	0.02	1.55	0.01	118	37	3.2
Cormorant No. 1	Demons Bluff Fm	2	5.10	0.05	2.06	0.02	39	95	0.4
Aroo No. 1	L. EVCM	1	6.05	0.82	22.80	0.04	365	10	37
Bass No. 1	Torquay Gp	6	0.70	0.02	0.26	0.08	34	213	0.2
	Torquay Gp	8	0.50	0.04	0.05	0.80	2	200	0.01
	U. EVCM	11	5.35	0.10	2.10	0.05	37	47	0.8
	U. EVCM	13	1.90	0.10	2.80	0.04	142	57	2.5
	U. EVCM	15	2.80	0.21	4.07	0.05	138	162	0.9
Bass No. 2	Torquay Gp	2	0.50	0.02	1.79	0.01	354	313	1.1
	U. EVCM	5	3.55	0.08	12.50	0.01	349	31	11
	L. EVCM	9	2.40	0.21	10.00	0.02	409	29	14
Bass No. 3	U. EVCM	8	1.05	0.04	1.00	0.04	91	240	0.4
	L. EVCM	10	20.10	1.21	46.70	0.03	226	10	23
	L. EVCM	11	2.40	0.13	4.74	0.03	192	11	18
	L. EVCM	13	0.60	0.02	0.03	0.67	2	18	0.1
Cormorant No. 1	U. EVCM	5	10.10	1.63	13.70	0.12	120	197	0.6
	U. EVCM	6	66.90*	14.50	182	0.08	250	33	7.6
Nangkero No. 1	U. EVCM	1	0.70	0.08	3.56	0.02	497	336	1.5
Narimba No. 1	L. EVCM	1	7.10	1.81	17.70	0.10	223	9	24
	L. EVCM	2	0.85	0.09	0.73	0.12	76	271	0.3
	L. EVCM	3	1.85	0.19	1.72	0.11	83	148	0.6
Poonboon No. 1	L. EVCM	2	65.80*	19.60	160	0.12	213	13	16
	L. EVCM	4	1.75	0.11	1.49	0.07	79	132	0.6
	L. EVCM	5	1.20	0.13	0.88	0.15	63	100	0.6
Snail No. 1	U. EVCM	2	2.65	3.86	4.07	0.95	8	114	0.07
	Otway Gp	3	4.15	3.03	3.14	0.96	3	150	0.02
Durroon No. 1	Otway Gp	3	1.80	0.01	0.60	0.02	33	69	0.5
	Otway Gp	4	4.50	0.17	0.98	0.17	18	9	2.0
	Otway Gp	5	3.75	0.23	2.28	0.10	55	9	5.9

\* Coal

Table -1 Rock-Eval pyrolysis data for some Bass Basin source rocks (Martin &amp; Saxby, 1980).

DURROON N°1

DEPTH K.B. FT.	STRATIGRAPHY	LITHOLOGY	SOURCE (Geochemistry)	Ro		VISUAL KEROGEN
				Range	Average	
P 4400	lower T. lilliei					Non marine, gas/cond prone, marginally mature for oil, immature for gas/cond.
P 4500	? lower T. lilliei					Mid Upper Cretaceous Unconform. (4492')
CH			TOC : 0.92%	0.38-0.67	0.54	Non-marine, poor source rock. Marginally mature for oil. Very heavy reworking of Permian & Triassic.
CH 4600						
CH			TOC : 1.46% TMAX = 434°C S1+S2 = 0.71 HI: 42/OI: 226	0.44-0.67	0.54	N. senectus & T pachyexinus zones not seen.
CH			TOC : 1.80% TMAX = 434°C S1+S2 = 0.51 HI: 24/OI: 136	0.41-0.61	0.49	
CH 4700						
CH P	C. triplex		TOC = 1.26%			Non-marine, excellent gas/cond. source, immature for oil. Fresh water microplankton.
CH 4800			TOC = 1.64% TMAX = 434°C S1+S2 = 1.16 HI: 64/OI: 149	0.47-0.63	0.54	
CH			TOC = 1.55%			
CH 4900			TOC = 1.69% TMAX = 435°C S1+S2 = 0.70 HI: 37/OI: 176	0.46-0.68	0.57	
CH						
CH 5000						
CH			TOC = 1.36%	0.44-0.74	0.58	
CH			TOC = 1.30%			
P 5100	C. triplex			0.35-0.70	0.52	Non-marine, excellent gas/cond source, immature for oil. Fresh water microplankton
CH 5200						
P 5300	C. triplex					Non-marine, gas/cond & oil prone. Fresh water micro plankton
CH 5400						
P 5500	C. triplex					Oil prone source approaching maturity, brackish environment. Minor Permian & Triassic reworking.
CH 5600						Top Early Cretaceous A. distocarinitus & P. pannosus zones not seen.
CH,P 5700	upper C. paradoxa		TOC = 1.13%			Non-marine fresh water micro-plankton liptinite rich (30-50%) Strongly oil prone near mature to mature for oil.
CH 5800						
CH 5900						
CH,P 6000	upper C. paradoxa		TOC = 1.26%			Non-marine fresh water plankton liptinite rich (30-50%) & strongly oil prone, near mature to mature for oil.
CH 6100						
CH,P 6200	upper C. paradoxa		TOC = 1.51%			Brackish, rare acritarchs, liptinite rich (30-50%) strongly oil prone, near mature to mature for oil.
CH 6300						
CH,P 6400						
CH,P 6500	lower C. paradoxa		TOC = 0.37%			Non-marine liptinite (50%) oil prone, near mature for oil

LATE CRETACEOUS

EARLY CRETACEOUS

Core N°1

365012

LEGEND  
CH — Geochemistry Sample  
P — Palynological Sample

**BRIDGE OIL LIMITED**  
 COMPILATION OF  
 PALYNOLOGICAL SOURCE  
 ROCK & VITRINITE  
 REFLECTANCE DATA  
 DURROON N°1  
 Author: H.H Date: Dec. '85 ENCL. 1.



OR-0336C

PALYNOLOGY OF ESSO DURROON-1,

BASS BASIN

BY

ROGER MORGAN

for Bridge Oil

October 1985.

Attachment 1

PALYNOLOGY OF ESSO DURROON-1,

BASS BASIN

D of M	A.O.	ED.	28 s.
D. DIR.	10 FEB 1986		E&IL
DEPT. OF MINES			
REF. No. 1226/86			

BY

ROGER MORGAN

for Bridge Oil

October 1985.

## PALYNOLOGY OF ESSO DURROON-1, BASS BASIN

BY

ROGER MORGAN

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I SUMMARY

4330 ft. (cutts): lower T. lillei Zone : Campanian : non-marine : gas/condensate prone : immature for gas/condensate : marginally mature for oil.

4510 ft. (cutts) : apparently T. lillei Zone : apparently Campanian : non-marine : poor source rock : marginally mature for oil

N. senectus and T. pachyexinus Zones not seen

4750-5500 ft. (cutts) : apparently all C. triplex Zone : Turonian-Coniacian: brackish to freshwater : gas/condensate prone at the top, oil prone at the base : immature for gas/condensate, marginally mature for oil.

A. distocarinatus and P. pannosus Zones not seen

5720-6250 ft. (cutts) : upper C. paradoxa Zone : mid Albian : brackish to freshwater : oil prone : marginally mature for oil

6490 ft. (cutts) : probably lower C. paradoxa Zone : mid Albian : non-marine oil prone: marginally mature to mature for oil

## II INTRODUCTION

The present study comprises 10 cuttings samples examined as part of a palynological and organic geochemical review for Bridge Oil.

The palynological occurrence data are computer plotted and presented as Appendix I. The environmental and organic geochemical data are presented as Appendix II. Figure 1 is a maturity profile for the well. Figure 2 is a summary of the zonation and the geology of the nearby Otway Basin.

The zonation is that of Helby, Morgan and Partridge (in prep.) and represents a synthesis of earlier work mostly of Dettmann (1963), Dettmann and Playford (1969), and Douglas (1976), Stover and Evans (1973) Stover and Partridge (1973) and Partridge (1973).

III PALYNOSTRATIGRAPHYA. 4330 ft. (cutts): lower T. lillei Zone

Assignment to the lower half of the T. lillei Zone is indicated by the toprange of common Nothofagidites senectus and Tricolpites sabulosus, and by the baserange of Triporopollenites sectilis, Stereisporites regium and Gambierina rudata. T. pachyexinus also occurs in this sample.

Non-marine environments are indicated by the abundance and diversity of the spores and pollen, and total absence of microplankton.

The dominance of amorphous vitrinite in the kerogen indicates that the rock is gas/condensate prone. Spore colours of light yellow-brown indicate that the rock is immature for gas/condensate, but just marginally mature for oil. The lack of any TOC data precludes any statement on the overall source rock potential.

B. 4510 ft. (cutts): apparently T. lillei Zone

The sample is very lean of palynomorphs comprising a mixture of Permian, Triassic, and late Cretaceous taxa. The common Permian and Triassic forms are reworked, and the late Cretaceous forms include Gambierina rudata, Tricolporites pachyexinus and frequent Nothofagidites senectus which would indicate a lower T. lillei Zone assignment. However, considering the very lean nature of the sample, the T.

Revised 11/11/68

lillei Zone material may be caved to this point from the rich interval above. There are no older indicators, and so the sample is tentatively included in the T. lillei Zone. The very heavy reworking may suggest proximity to an unconformity.

Non-marine environments are indicated by the lack of microplankton, but it is uncertain whether these specimens are in place or caved.

The kerogen is dominated by inertinite and therefore lacks significant hydrocarbon prone source material. In addition, it is lean, and presumably lacks sufficient organic material to generate. Spore colours of yellow-brown indicate immaturity for gas/condensate and marginal maturity for oil.

- C. The N. senectus and T. pachyexinus Zones, representing the Santonian to lower Campanian interval, were not seen.
- D. 4750-5500 ft. (cutts) : apparently all C. triplex Zone

Assignment to the C. triplex Zone is indicated by the baserange of Proteacidites spp. and Phyllocladidites mawsonii at 5500 ft. (cutts) in the absence of younger indicators considered to be in place. Rare specimens of Gambierina rudata, Malvacipollis subtilis, Nothofagitites senectus, Tricolpites confessus and Triporopollenites sectilis occur scattered through the interval, but are considered to be caved, as they have significantly lighter spore colours than the majority of the specimens which are



AGE	SPORE- POLLEN ZONES		MICRO- PLANKTON ZONES		LITHOSTRATIGRAPHY
Maastrichtian	T. longus	Nothofagidites	I. druggii	D. pellucida	Timboon Sand
Campanian	T. lillei		I. korojonense		
	N. senectus		X. australls		
Santonian	T. pachyexinus		N. aceras	Paaratte Formation	
Coniacian			I. cretaceum		
Turonian	C. triplex		O. porifera	Belfast Mudstone	
Cenomanian	A. distocarinatus		C. striatoconus	Flaxman Formation	
			P. infusorioides		
			D. multiplum		
Albian	P. pannosus C. paradoxa C. striatus		X. asperatus	Waare Formation	
			P. ludbrookiae		
			C. denticulata		
Aptian	C. hughesi		M. tetracantha	Pretty Hill Formation	
			D. davidii		
Barremian	F. wonthaggiensis (lower C. hughesi of Dettmann)		O. operculata	Otway Group	
			O. cinctum		
Hauterivian	C. hughesi		M. australls	Pretty Hill Formation	
			M. testudinaria		
Valanginian	C. australlsensis (C. stylosus of Dettmann)		P. burgeri	Pretty Hill Formation	
			S. tabulata		
			S. areolata		
Berriasian	C. australlsensis (C. stylosus of Dettmann)		E. torynum	Pretty Hill Formation	
			B. reticulatum		
			D. lobosplum		
			C. delicata		
			K. wisemaniae		
			P. lehlense		

FIGURE 2. REGIONAL FRAMEWORK, OTWAY BASIN

considered to be in place. Since the samples are cuttings, some doubt may exist concerning the location of the zone base, and it may be picked slightly too low. The kerogen change at 5500 ft., and the presence of Crybelosporites striatus suggest that this sample may belong to the underlying zone. Minor Permian and Triassic reworking occurs at the zone base.

Non-marine environments are indicated by the presence of freshwater microplankton (Schizosporis, Morkallacysta) in all except the basal sample. The deepest sample (5500 ft.) contains rare Micrhystridium spp. suggesting brackish environments.

The top two samples (4750 ft. and 5060 ft.) are dominated by amorphous vitrinite and so are strongly gas/condensate prone. The available TOC data generated by Analabs indicates abundant organic matter (.92-1.8%). The interval is therefore an excellent gas/condensate source interval, but spore colours indicate its immaturity for oil.

The lower two samples have more oil potential. The sample at 5260 ft. contains high proportions of both vitrinite and liptinite and is therefore both gas/condensate and oil prone. The sample at 5500 ft. is liptinite dominated and therefore oil prone. Spore colours indicate immaturity for gas/condensate but marginal maturity approaching maturity for oil. No organic content data are available for this interval.

- E. The A. distocarinatus and P. pannosus Zones representing the latest Albian and Cenomanian were not seen.
- F. 5720-6250 ft. (cutts) : upper C. paradoxa Zone

Zone fossils are extremely scarce in this interval, but assignment to the upper C. paradoxa Zone is indicated by the baserange of Perotriletes majus at 6250 ft., in the absence of older and younger indicators. The top range of Dictyotosporites speciosus at 6490 ft. below, and the presence of common Crybelosporites striatus through the interval, confirm the assignment. No definite specimens of either Pilosporites grandis or Coptospora paradoxa were seen, although these species are consistent in this zone in the Otway Basin. Rare Triassic and Permian reworking has occurred.

Non-marine environments are indicated for the upper two samples (5720 ft and 6010 ft) by the abundant spore pollen and presence of freshwater microplankton (Schizosporis and Morkallacysta). Rare spiny acritarchs (Micrhystridium) occur at 6250 ft. and indicate brackish conditions.

These samples are rich in liptinite (30-50% of the kerogen) and so are strongly oil prone. Spore colours of brown to yellow-brown indicate maturity or near maturity for oil and near marginal maturity for gas/condensate. The lack of any organic content data is frustrating, as it precludes full assessment of source rock potential.

- G. 6490 ft. (cutts) : probably lower C. paradoxa Zone

Assignment to the lower C. paradoxa or older Zones is indicated by the toprange of Dictyotosporites speciosus and the absence of Perotriletes majus. The presence of Crybelosporites striatus indicates assignment to the C. striatus or younger Zones. Thus the sample must belong to the C. striatus to lower C. paradoxa interval, although its location within this interval cannot be precisely determined. However, given the assignment of the overlying sample, and the scarcity of C. paradoxa in this well, assignment to the lower C. paradoxa Zone is more likely than to the C. striatus Zone. Specimens of a Coptospora species similar to Coptospora sp. B Dettmann was seen.

Non-marine environments are indicated by the absence of microplankton and dominance of spores and pollen.

The high liptinite content (50%) in the kerogen indicates that the rock is oil prone, while spore colours indicate its high marginal mature to mature condition for oil. The lack of organic content data precludes full source rock assessment.

DURROON #1 DINOS

CHECKLIST OF GRAPHIC ABUNDANCE BY LOWEST APPEARANCE

- █ = Abundant
- ▬ = Common
- ▬ = Few
- ▬ = Rare
- ▬ = Very Rare
- ? = Questionably Present
- . = Not Present

SCHIZOSPORIS PARVUS  
 SCHIZOSPORIS RETICULATA  
 MICRHYSTRIDIUM  
 MORKALLACYSTA GRANULAR  
 MORKALLACYSTA SP.  
 SCHIZOSPORIS PSILATUS  
 MORKALLACYSTA VERRUCATE

	SCHIZOSPORIS PARVUS	SCHIZOSPORIS RETICULATA	MICRHYSTRIDIUM	MORKALLACYSTA GRANULAR	MORKALLACYSTA SP.	SCHIZOSPORIS PSILATUS	MORKALLACYSTA VERRUCATE
00 00 00 00	.	.	.	.	.	.	.
4330' CUTTS	.	.	.	.	.	.	.
4510' CUTTS	.	.	.	.	.	.	.
4750' CUTTS	.	.	.	.	.	.	.
5060' CUTTS	.	.	.	.	▬	▬	.
5260' CUTTS	.	.	.	.	▬	▬	.
5500' CUTTS	.	.	▬	.	▬	.	.
5720' CUTTS	▬	.	.	.	.	▬	▬
6010' CUTTS	.	.	.	.	.	.	.
6250' CUTTS	▬	.	▬	▬	▬	▬	.
6490' CUTTS	▬	▬	.	.	.	.	.

IV CONCLUSIONS AND RECOMMENDATIONSA. Conclusions

1. The studied sequence appears to comprise mid Albian (C. paradoxa), Turonian-Coniacian (C. triplex) and Campanian (T. lillei) rocks, separated by unconformities. Environments are almost all non-marine, with only minor brackish influence.
2. The Campanian and Turonian-Coniacian intervals are largely gas/condensate prone, but immature. TOC data is available for only part of the interval, and indicates excellent source rock potential.
3. The mid Albian is oil prone, and close to maturity for oil generation. No TOC data are available, and so the potential cannot be fully assessed. If this section has sufficiently high organic content and can be found slightly more deeply buried, it has enormous potential for oil generation, as it is over 1000 feet thick.

B. Recommendations

1. Further TOC and Rock Eval work is vital to fully assess the mid Albian as an oil source. Sampling deeper in the well (below 6250 ft.) would give an indication of the source potential of the rocks that are mature in the well section.

V. REFERENCES

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- Stover, L.E. and Partridge, A.D. (1973) Tertiary and Late Cretaceous Spores and Pollen from the Gippsland Basin, Southeastern Australia Proc. Roy. Soc. Vict. 85 (2), 237-286.

DURROON #1 PALYNOLOGICAL DATA

ROGER P. MORGAN Ph.D. Palynological Consultant

Box 161, Maitland, South Australia, 5573.  
phone (088) 32 2795 ... fax (088) 32 2798

CLIENT: Bridge 011

WELL: Durroon #1

FIELD / AREA: Bass Basin

ANALYST: Roger Morgan

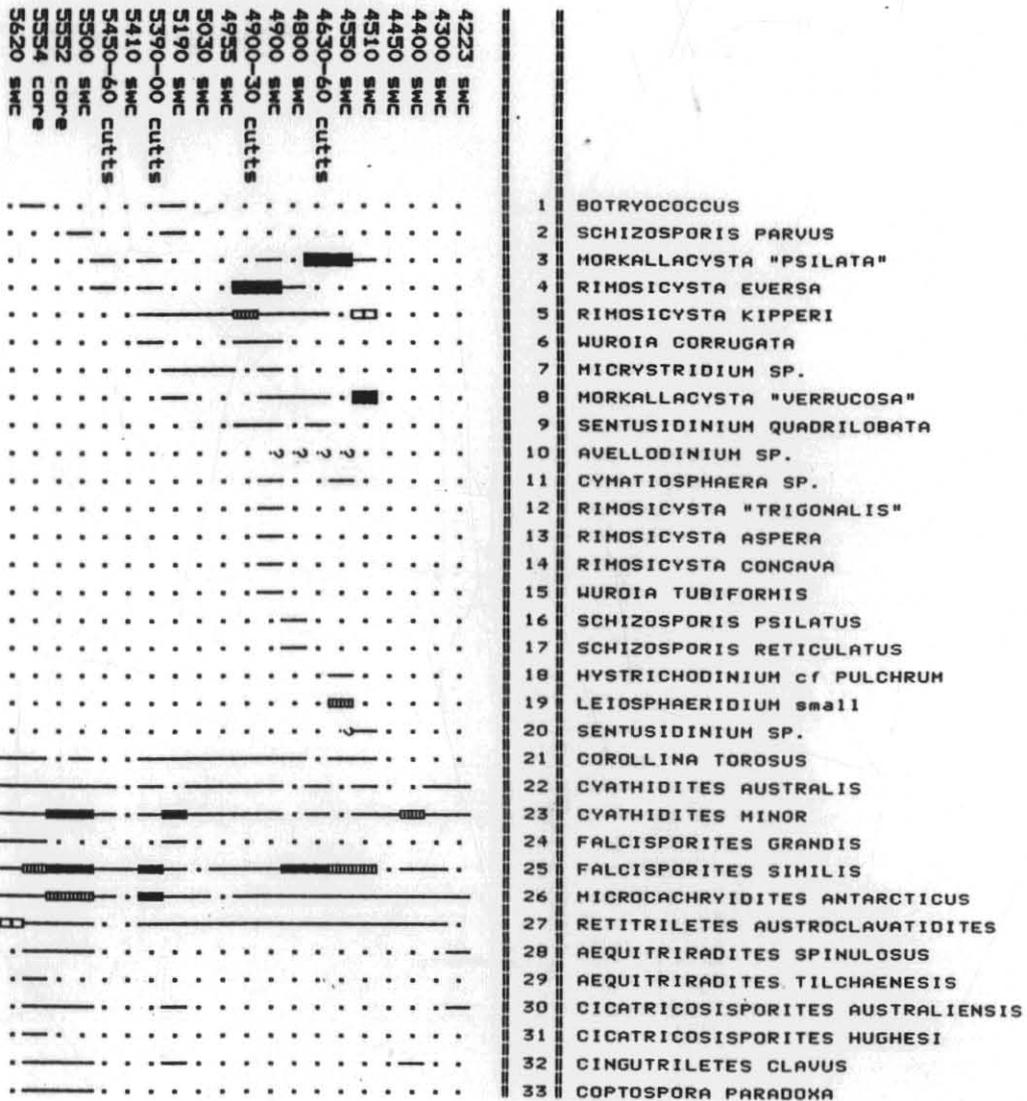
DATE: February '91

NOTES: all sample depths are in feet

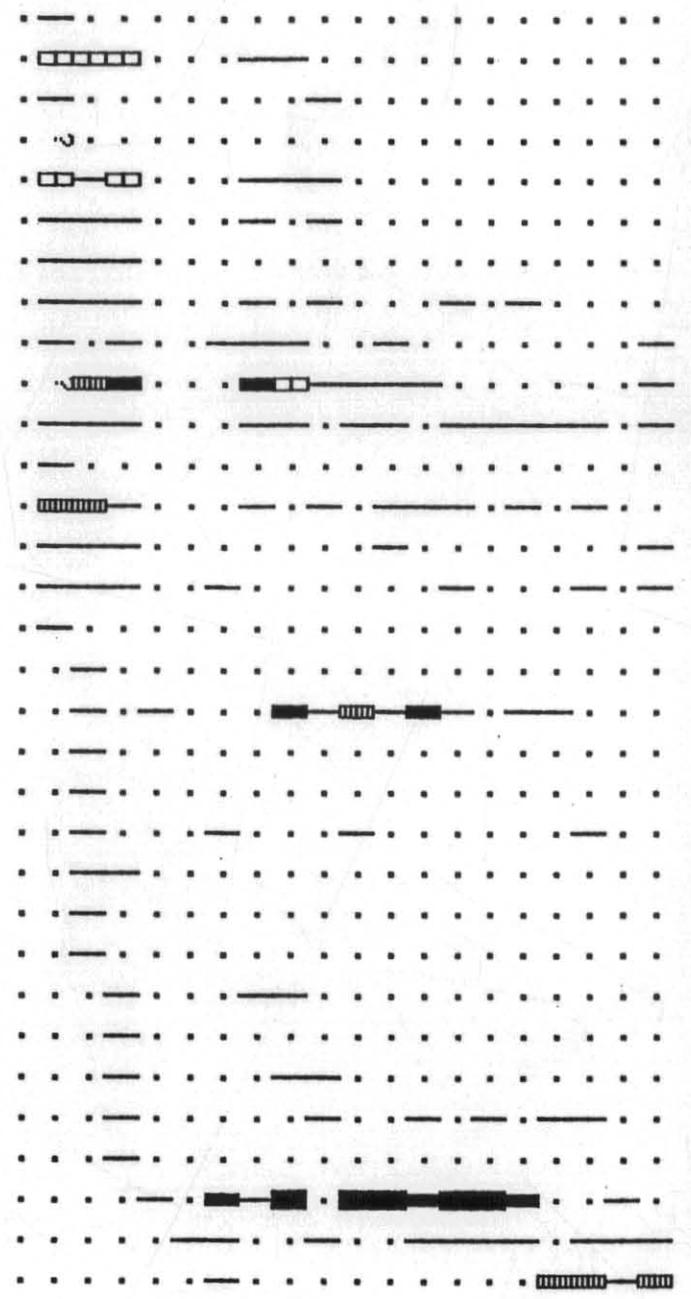
RANGE CHART OF GRAPHIC ABUNDANCES BY LOWEST APPEARANCE: dinos & s/p

Key to Symbols

-  = Very Rare
-  = Rare
-  = Few
-  = Common
-  = Abundant
-  = Questionably Present
-  = Not Present



23 SMC  
 00 SMC  
 00 SMC  
 50 SMC  
 19 SMC  
 50 SMC  
 30-60 cutts  
 00 SMC  
 00 SMC  
 00-30 cutts  
 55 SMC  
 30 SMC  
 90 SMC  
 90-00 cutts  
 10 SMC  
 50-60 cutts  
 00 SMC  
 52 pre  
 54 core  
 20 SMC



- 34 COUPERISPORITES TABULATUS
- 35 CRYBELOSPORITES STRIATUS
- 36 DICTYOTOSPORITES COMPLEX
- 37 DICTYOTOSPORITES SPECIOSUS
- 38 FORAMINISPORIS ASYMMETRICUS
- 39 FORAMINISPORIS DAILYI
- 40 FOVEOTRILETES PARVIRETUS
- 41 GLEICHENIIDITES
- 42 OSMUDACIDITES WELLMANII
- 43 PHYLLOCLADIDITES EUNUCHUS
- 44 PODOSPORITES MICROSACCATUS
- 45 RETITRILETES WATHARODENSIS
- 46 STEREISPORITES ANTIQUISPORITES
- 47 TRIPOROLETES RADIATUS
- 48 TRIPOROLETES RETICULATUS
- 49 VELOSPORITES TRIQUETRUS
- 50 AEQUITRIRADITES VERRUCOSUS
- 51 ARAUCARIACITES AUSTRALIS
- 52 ARCELLISPORITRES SP.
- 53 BALMEISPORITES HOLODICTYUS
- 54 CERATOSPORITES EQUALIS
- 55 DICTOPHYLLIDITES SPP
- 56 MATONISPORITES COOKSONIAE
- 57 RETITRILETES EMINULUS
- 58 CICATRICOSISPORITES CUNEIFORMIS
- 59 CONTIGNISPORITES COOKSONIAE
- 60 CYCADOPITES FOLLICULARIS
- 61 DACRYCARPITES AUSTRALIENSIS
- 62 SESTROSPORITES PSEUDOALVEOLATUS
- 63 DILWYNITES GRANULATUS
- 64 PROTEACIDITES SP
- 65 NOTHOFAGIDITES ENDURUS



Index numbers are the columns in which species appear.

INDEX NUMBER	SPECIES
28	AEGUITRIRADITES SPINULOSUS
29	AEGUITRIRADITES TILCHAENESIS
50	AEGUITRIRADITES VERRUCOSUS
80	AMOSOPOLLIS CRUCIFORMIS
85	APPENDICISPORITES DISTOCARINATUS
51	ARAUCARIACITES AUSTRALIS
52	ARCELLISPORITES SP.
83	AUSTRALOPOLLIS OBSCURUS
10	AVELLODINIUM SP.
53	BALMEISPORITES HOLODICTYUS
1	BOTRYOCOCCUS
54	CERATOSPORITES EQUALIS
30	CICATRICOSISPORITES AUSTRALIENSIS
58	CICATRICOSISPORITES CUNEIFORMIS
31	CICATRICOSISPORITES HUGHESI
76	CICATRICOSISPORITES LUDBROOKIAE
32	CINGUTRILETES CLAVUS
59	CONTIGNISPORITES COOKSONIAE
79	COPTOSPORA "PILEOSA"
33	COPTOSPORA PARADOXA
21	COROLLINA TOROSUS
34	COUPERISPORITES TABULATUS
35	CRYBELOSPORITES STRIATUS
22	CYATHIDITES AUSTRALIS
23	CYATHIDITES MINOR
60	CYCADOPITES FOLLICULARIS
73	CYCLOSPORITES HUGHESI
11	CYMATIOSPHAERA SP.
1	DACRYCARPITES AUSTRALIENSIS
1	DICTOPHYLLIDITES SPP
36	DICTYOTOSPORITES COMPLEX
37	DICTYOTOSPORITES SPECIOSUS
63	DILWYNITES GRANULATUS
24	FALCISPORITES GRANDIS
25	FALCISPORITES SIMILIS
38	FORAMINISPORIS ASYMMETRICUS
39	FORAMINISPORIS DAILYI
74	FORAMINISPORIS WONTHAGGIENSIS
40	FOVEOTRILETES PARVIRETUS
81	GAMBIERINA RUDATA
41	GLEICHENIIDITES
84	HERKOSPORITES ELLIOTTII
18	HYSTRICHODINIUM cf PULCHRUM
19	LEIOSPHAERIDIUM small
75	LEPTOLEPIDITES VERRUCATUS
77	LYGISTEPOLLENITES FLORINII
56	MATONISPORITES COOKSONIAE
26	MICROCACHRYIDITES ANTARCTICUS
82	MICROFOVEOLATOSPORIS SP.
7	MICRYSTRIDIUM SP.
3	MORKALLACYSTA "PSILATA"
8	MORKALLACYSTA "VERRUCOSA"
69	NOTHOFAGIDITES EMARCIDUS
65	NOTHOFAGIDITES ENDURUS
7	NOTHOFAGIDITES SENECTUS
70	OSMUDACIDITES WELLMANII
66	PEROTRILETES MAJUS
86	PEROTRILETES MORGANII
43	PHIMOPOLLENITES PANNOSUS
67	PHYLLOCLADIDITES EUNUCHUS
72	PHYLLOCLADIDITES MAWSONII
44	PHYLLOCLADIDITES VERRUCATUS
64	PODOSPORITES MICROSACCATUS
27	PROTEACIDITES SP
57	RETITRILETES AUSTRACLAVATIDITES
78	RETITRILETES EMINULUS
45	RETITRILETES NODOSUS
12	RETITRILETES WATHAROOENSIS
13	RIMOSICYSTA "TRIGONALIS"
14	RIMOSICYSTA ASPERA
4	RIMOSICYSTA CONCAVA
5	RIMOSICYSTA EVERSA
2	RIMOSICYSTA KIPPERI
16	SCHIZOSPORIS PARVUS
17	SCHIZOSPORIS PSILATUS
9	SCHIZOSPORIS RETICULATUS
20	SENTUSIDINIUM QUADRILOBATA
62	SENTUSIDINIUM SP.
46	SESTROSPORITES PSEUDOALVEOLATUS
90	STEREISPORITES ANTIQUISPORITES
89	STEREISPORITES REGIUM
68	TRICOLPITES CONFESSUS
88	TRICOLPITES GILLII
91	TRICOLPITES SABULOSUS
71	TRICOLPITES SP
47	TRICOLPITES SP.
48	TRIPOROLETES RADIATUS
49	TRIPOROLETES RETICULATUS
49	USI NODOSITES TOYNEIENSIS

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	AGE	SPORE - POLLEN ZONES	DINOFLAGELLATE ZONES	
Early Tertiary	Early Oligocene	<i>P. tuberculatus</i>		
	Late Eocene	upper <i>N. asperus</i>	<i>P. comatum</i>	
		middle <i>N. asperus</i>	<i>V. extensa</i>	
	Middle Eocene	lower <i>N. asperus</i>	<i>D. heterophlycta</i>	
			<i>W. echinosuturata</i>	
	Early Eocene		<i>P. asperopolus</i>	<i>W. edwardsii</i>
			upper <i>M. diversus</i>	<i>W. thompsonae</i>
				<i>W. ornata</i>
			middle <i>M. diversus</i>	<i>W. weidmannensis</i>
			lower <i>M. diversus</i>	<i>W. hyperacantha</i>
Paleocene	upper <i>L. balmei</i>		<i>A. homomorpha</i>	
	lower <i>L. balmei</i>		<i>E. crassitabulata</i>	
Late Cretaceous	Maastrichtian		<i>T. longus</i>	
	Campanian		<i>T. illiei</i>	<i>I. korojonense</i>
			<i>N. senectus</i>	<i>X. australis</i>
	Santonian	<i>T. pachyexinus</i>	<i>N. aceras</i>	
			<i>I. cretaceum</i>	
	Coniacian		<i>C. porifera</i>	
	Turonian		<i>C. triplex</i>	<i>C. striatoconus</i>
				<i>P. infusorioides</i>
	Cenomanian	<i>A. distocarinatus</i>		
Early Cretaceous	Albian	Late	<i>P. pannosus</i>	
		Middle	upper <i>C. paradoxa</i>	
			lower <i>C. paradoxa</i>	
	Aptian	Early	<i>C. striatus</i>	
			upper <i>C. hughesi</i>	
			lower <i>C. hughesi</i>	
	Barremian			
	Hauterivian	<i>F. wonthaggiensis</i>		
	Valanginian	upper <i>C. australiensis</i>		
	Berriasian	lower <i>C. australiensis</i>		
Juras.	Tithonian	<i>R. watheroensis</i>		

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DURROON #1 S/P

CHECKLIST OF GRAPHIC ABUNDANCE BY LOWEST APPEARANCE

- Abundant
- ▒ Common
- ▒ Few
- ▒ Rare
- ▒ Very Rare
- ⊗ Questionably Present
- Not Present

Sample No.	Species	Abundance
00	00	00
00	00	00
4330	CUTTS	—
4510	CUTTS	—
4750	CUTTS	—
5060	CUTTS	—
5260	CUTTS	—
5500	CUTTS	—
5720	CUTTS	—
6010	CUTTS	—
6250	CUTTS	—
6490	CUTTS	—
1	BALMEISPORITES HOLODICTYUS	—
2	CICATRICOSISPORITES AUSTRALIENSIS	—
3	COPTOSPORA CF SP. B	—
4	COROLLINA TOROSUS	—
5	CRYBELOSPORITES STRIATUS	—
6	CYATHIDITES AUSTRALIS	—
7	CYATHIDITES MINOR	—
8	DICTYOTOSPORITES COMPLEX	—
9	DICTYOTOSPORITES SPECIOSUS	—
10	DILWYNITES GRANULATUS	—
11	FALCISPORITES GRANDIS	—
12	FALCISPORITES SIMILIS	—
13	FORAMINISPORIS DAILYI	—
14	ISCHYOSPORITES PUNCTATUS	—
15	KLUKISPORITES SCABERIS	—
16	LEPTOLEPIDITES VERRUCATUS	—
17	OSMUNDACIDITES WELLMANII	—
18	PEROTRILETES OUBATUS	—
19	PODOSPORITES MICROBACCATUS	—
20	REITRILETES AUSTROROCLAVATIDITES	—
21	REITRILETES FACETUS	—
22	STEREISPORITES ANTIQUASPORITES	—
23	AEQUITRIRADITES SP.	—
24	ARAUCARIACITES AUSTRALIS	—
25	ARAUCASIACITES FISSUS	—
26	CERATOSPORITES EQUALIS	—
27	CINGUTRILETES CLAVUS	—
28	DICTYOTOSPORITES COMPLEX COARSE	—
29	FORAMINISPORIS ASYMMETRICUS	—
30	FOVEOTRILETES PARVIRETUS	—
31	GLEICHENIIDITES	—
32	LEPTOLEPIDITES MAJOR	—
33	MICROCACHRYIDITES ANTARCTICUS	—

00 00 00 00  
 4330 CUTTS  
 4510 CUTTS  
 4750 CUTTS  
 5060 CUTTS  
 5260 CUTTS  
 5500 CUTTS  
 5720 CUTTS  
 6010 CUTTS  
 6250 CUTTS  
 6490 CUTTS

34	NEORAISTRICKIA TRUNCATA	.....
35	PEROTRILETES MAJUS	.....
36	TRICOLPITES VARIABILIS	.....
37	TRIPOROLETES RADIATUS	.....
38	TRIPOROLETES RETICULATUS	.....
39	VITREISPORITES PALLIDUS	.....
40	CALLIALASPORITES TURBATUS	.....
41	CICATRICOSISPORITES LUDBROOKIAE	.....
42	COPTOSPORA PARADOXA	.....
43	TRICOLPITES GILLII	.....
44	CONTIGNISPORITES COOKSONIAE	.....
45	AUSTRALOPOLLIS OBSCURUS	.....
46	CYCADOPITES FOLLICULARIS	.....
47	DICTYOPHILLIDITES HARRISII	.....
48	GAMBIERINA RUDATA	.....
49	HALORAGACIDITES HARRISII	.....
50	MALVACIPOLLIS SUBTILIS	.....
51	NOTHOFAGIDITES EMARCIDUS	.....
52	NOTHOFAGIDITES SENECTUS	.....
53	PERINOPOLLENITES ELATOIDES	.....
54	PHYLOCLADIDITES MAWSONII	.....
55	PROTEACIDITES SPP.	.....
56	TRICOLPITES CONFESSUS	.....
57	TRIPOROPOLLENITES SECTILIS	.....
58	ANNULISPORITES FOLLICULOSA	.....
59	LYGISTEPOLLENITES FLORINII	.....
60	STEREISPORITES (TRIPUNCTISPORIS) SPP.	.....
61	CYCLOSPORITES HUGHESI	.....
62	HOEGISPORIS	.....
63	TRICOLPITES SABULOSUS	.....
64	NOTHOFAGIDITES ENDURUS	.....
65	PERIPOROPOLLENITES POLYORATUS	.....
66	TRICOLPORITES PACHYEXINUS	.....

365034

00 00 00 00  
4330' CUTTS  
4510' CUTTS  
4750' CUTTS  
5060' CUTTS  
5260' CUTTS  
5500' CUTTS  
5720' CUTTS  
6010' CUTTS  
6250' CUTTS  
6490' CUTTS

67 CAMEROZONOSPORITES OHAIENSIS  
68 NOTHOFAGIDITES HETERUS  
69 PROTEACIDITES AMOLOSEXINUS  
70 STEREISPORITES REGIUM  
71 TRICOLPITES HAIPAWAENSIS

## SPECIES LOCATION INDEX

Index numbers are the columns in which species appear.

INDEX NUMBER	SPECIES
23	AEGUITRIRADITES SP.
58	ANNULISPORITES FOLLICULOSA
24	ARAUCARIACITES AUSTRALIS
25	ARAUCASIACITES FISSUS
45	AUSTRALOPOLLIS OBSCURUS
1	BALMEISPORITES HOLODICTYUS
40	CALLIALASPORITES TURBATUS
67	CAMEROZONOSPORITES OHAIENSIS
26	CERATOSPORITES EQUALIS
2	CICATRICOSISPORITES AUSTRALIENSIS
41	CICATRICOSISPORITES LUDBROOKIAE
27	CINGUTRILETES CLAVUS
44	CONTIGNISPORITES COOKSONIAE
3	COPTOSPORA CF SP.B
42	COPTOSPORA PARADOXA
4	COROLLINA TOROSUS
5	CRYBELOSPORITES STRIATUS
6	CYATHIDITES AUSTRALIS
7	CYATHIDITES MINOR
46	CYCADOPITES FOLLICULARIS
61	CYCLOSPORITES HUGHESI
47	DICTYOPHILLIDITES HARRISII
8	DICTYOTOSPORITES COMPLEX
28	DICTYOTOSPORITES COMPLEX COARSE
9	DICTYOTOSPORITES SPECIOSUS
10	DILWYNITES GRANULATUS
11	FALCISPORITES GRANDIS
12	FALCISPORITES SIMILIS
29	FORAMINISPORIS ASYMMETRICUS
13	FORAMINISPORIS DAILYI
30	FOVEDTRILETAS PARVIRETUS
48	GAMBIERINA RUDATA
31	GLEICHENIIDITES
49	HALORAGACIDITES HARRISII
62	HOEGISPORIS
14	ISCHYOSPORITES PUNCTATUS
15	KLUKISPORITES SCABERIS
32	LEPTOLEPIDITES MAJOR
16	LEPTOLEPIDITES VERRUCATUS
59	LYGISTEPOLLENITES FLORINII
50	MALVACIPOLLIS SUBTILIS
33	MICROCACHRYIDITES ANTARCTICUS
34	NEORAISTRICKIA TRUNCATA
51	NOTHOFAGIDITES EMARCIDUS
64	NOTHOFAGIDITES ENDURUS

64	NOTHOFAGIDITES ENDURUS
68	NOTHOFAGIDITES HETERUS
52	NOTHOFAGIDITES SENECTUS
17	OSMUNDACIDITES WELLMANII
53	PERINOPOLLENITES ELATOIDES
65	PERIPOROPOLLENITES POLYORATUS
18	PEROTRILETES JUBATUS
35	PEROTRILETES MAJUS
54	PHYLOCLADIDITES MAWSONII
19	PODOSPORITES MICROSACCATUS
69	PROTEACIDITES AMOLOSEXINUS
55	PROTEACIDITES SPP.
20	RETITRILETES AUSTRICLAVATIDITES
21	RETITRILETES FACETUS
60	STEREISPORITES (TRIPUNCTISPORIS) SPP.
22	STEREISPORITES ANTIQUASPORITES
70	STEREISPORITES REGIUM
56	TRICOLPITES CONFESSUS
43	TRICOLPITES GILLII
63	TRICOLPITES SABULOSUS
36	TRICOLPITES VARIABILIS
71	TRICOLPITES WAIPAWAENSIS
66	TRICOLPORITES PACHYEXINUS
37	TRIPOROLETES RADIATUS
38	TRIPOROLETES RETICULATUS
57	TRIPOROPOLLENITES SECTILIS
39	VITREISPORITES PALLIDUS



# PETROLEUM GEOCHEMISTRY

HYDROCARBON SOURCE ROCK

EVALUATION STUDY

DURROCK 1

Prepared for

BRIDGE OIL LTD.

OCTOBER 1985



Attachment 2

## ANALABS

A Division of Macquarie Petroleum Pty. Ltd.

52 MURRAY ROAD, WELSHPOOL, W.A. 6106

Telephone: (09) 458 7999 Telex: ANALAB AA92560

**CONTENTS**

Summary

Introduction

Discussion of Results

**Figures:**

1. Hydrocarbon Source Rock Evaluation
2. Durroon #1 Hydrogen Index vs,  $T_{max}$
- 3a. Vitrinite Reflectance and Coal Maceral Identification
- 3b. Vitrinite Reflectance and Coal Maceral Identification

**Tables:**

1. Rock-Eval Pyrolysis
2. Core Description

**Appendix 1** Theory and Methods

365041

HYDROCARBON SOURCE ROCK

EVALUATION STUDY

DURROON 1

SUMMARY

D of M	A.O.	C.O.	E.O.
D. DIR.	10 FEB 1986		RECEIVED
	DEPT. OF MINES		
	REF. No. 1226/80		

Organic geochemical analyses performed on ten cuttings samples from 4540ft to 5040ft in the Durroon 1 well have indicated the following:

- The rocks between 4540ft and 5040ft have attained marginally mature maturation levels, and hence are considered to be in the initial stages of hydrocarbon generation. At this maturity, it is doubtful that any significant oil generation could have occurred.
- The sediments between 4540ft and 5040ft contain good amounts of organic matter, but produced low pyrolysis yields. The organic matter is dominated by inertinite and vitrinite, which are normally considered to be gas prone. In addition iron oxides are abundant which suggest the organic matter may be poorly preserved. As a result, these low maturity rocks have very limited oil generating capability, but may have moderate to good gas source potential at optimum maturity.

INTRODUCTION

Organic geochemical analyses have been performed on ten cuttings samples from 4540ft to 5040ft in the Durroon 1 well.

The purpose of this study has been to evaluate the thermal maturity and hydrocarbon source characteristics of the sediments analysed from this well.

Analytical

The samples from this well were assigned the Analabs Job Number 40088. Initially all ten samples were submitted to % total organic carbon determination, followed by Rock-Eval pyrolysis analysis on five selected samples. Five samples were also chosen for vitrinite reflectance/coal maceral descriptions and sent to Professor Alan Cook of Keiraville Konsultants.

The results may be located in the following figures and tables:

<u>Type of Analysis</u>	<u>Figure</u>	<u>Table</u>
% total organic carbon determination	1	1
Rock-Eval pyrolysis	1,2	1
Vitrinite reflectance/coal maceral description	1,3	2

A description of these analyses may be found in the Theory and Methods section located at the back of this report.

General Information

Copies of this report have been sent to Mr. Herman Huizinga of Bridge Oil Limited, located in Sydney, New South Wales. This work was authorised by Mr Huizinga and submitted under Purchase Order No. 6109. Any questions related to this study may be directed to Paul Tybor or Garry Woodhouse of Analabs, located in Perth, Western Australia.

All data and interpretations presented herein are proprietary to Bridge Oil Limited, are treated as highly confidential material by all Analabs personnel.

DISCUSSION OF THE RESULTSA. Thermal Maturity of Sediments

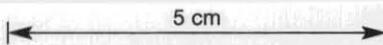
The rocks analysed between 4540ft and 5020ft in the Durroon 1 well have experienced a mild geothermal history. Vitrinite reflectance varies from a marginally mature 0.54% Ro at 4540ft to a marginally mature 0.58% Ro at 5020ft. At these low levels of alteration, the rocks are in the initial stages of petroleum generation. It is doubtful that these sediments could have generated significant amounts of petroleum.

The Tmax temperatures support the marginal maturity of these rocks as based on vitrinite reflectance, with temperatures ranging from 434 to 436 Deg. C. This temperature range corresponds to marginally/moderately mature maturation levels.

B. Hydrocarbon Source Character

The samples from 4540ft to 5040ft contain good amounts of organic matter (% TOC 1.0 - 2.0) but produced low pyrolysis yields ( $S_1+S_2$ ). The maceral descriptions indicate an abundance of inertinite and vitrinite organic matter types, which are generally held to be gas prone. Exinite is present in only minor quantities, with the exception of the 4780ft sample, where it is the dominant maceral. However, even this exinite rich sample still produced low pyrolysis yields. Professor Cook observed an abundance of iron oxides, which indicate poor preservation of organic matter. This condition of the organic matter has apparently affected its source quality, as reflected in the low hydrogen indices computed for all samples.

In summary, the good amounts of organic matter contained in these sediments is predominantly gas-prone and apparently poorly preserved. These factors, combined with the low maturity of the sequence, make the rocks analysed from this well poor oil source rocks. At higher maturities, these sediments may generate varying amounts of gas.



365044

FIGURE 1  
OCTOBER 1985

# ANA-LOG

## HYDROCARBON SOURCE ROCK EVALUATION

BRIDGE OIL LIMITED  
DURROON 1

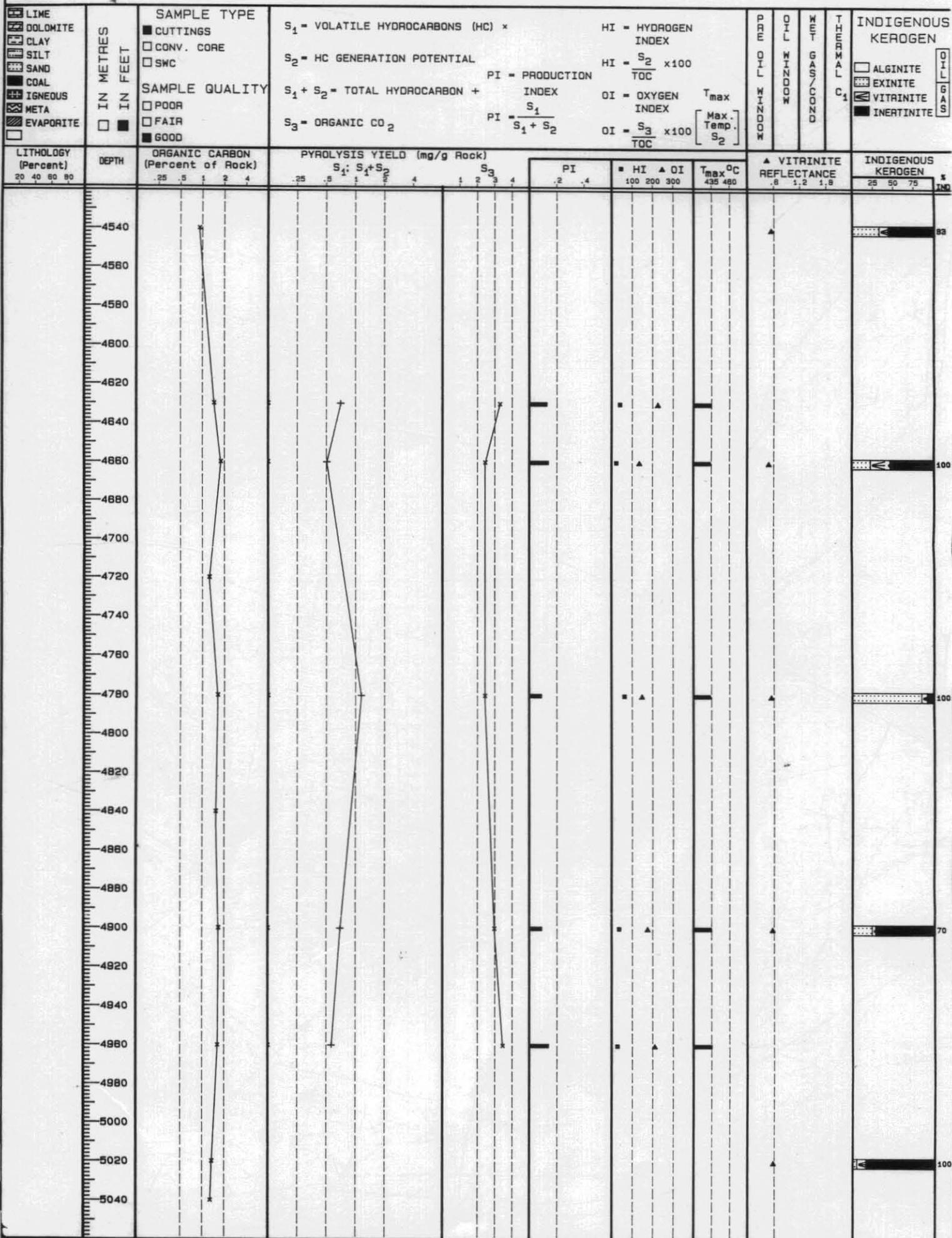
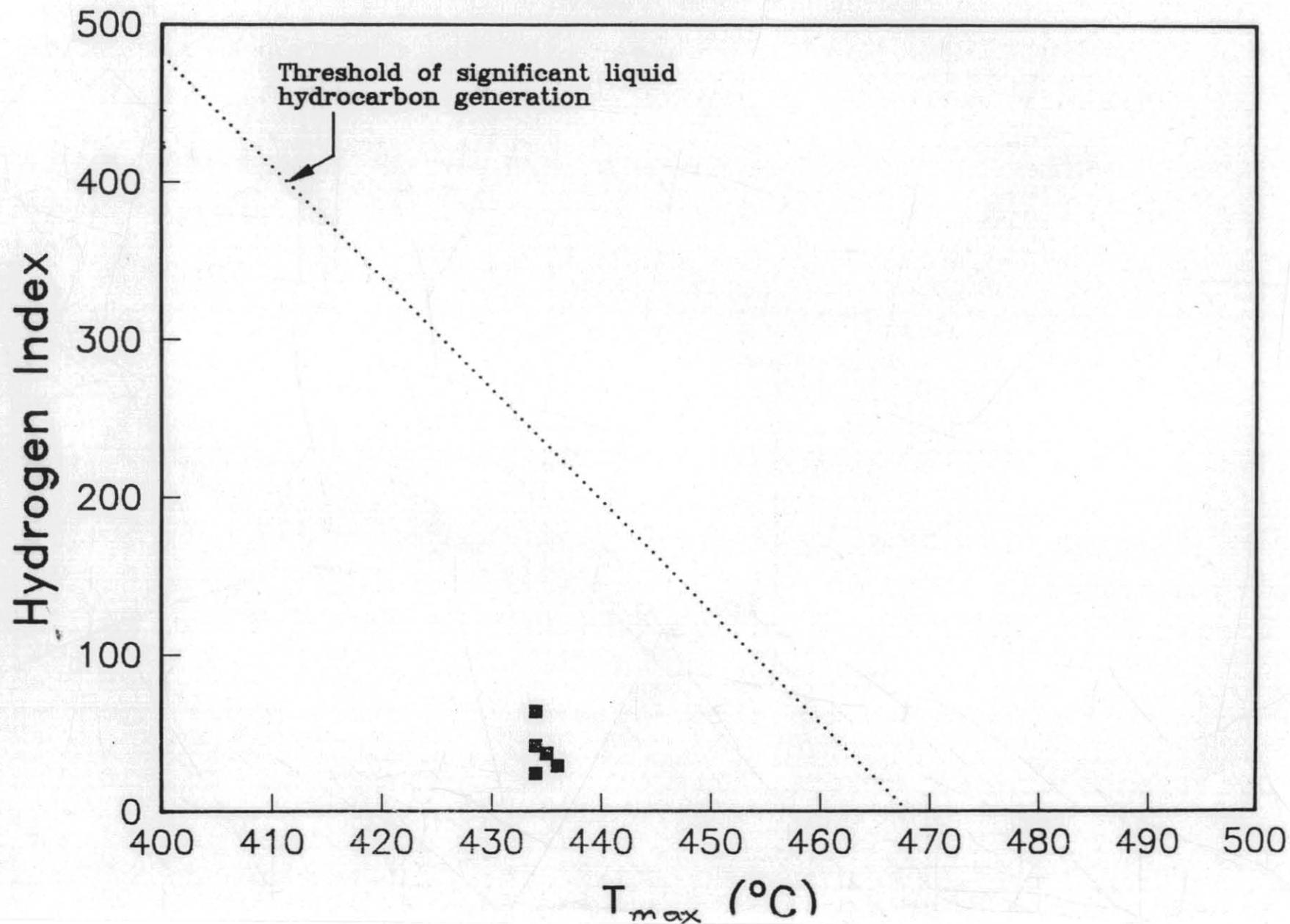


FIGURE 2  
DURROON 1  
HYDROGEN INDEX vs  $T_{max}$

5 cm



365045

FIGURE : 3a

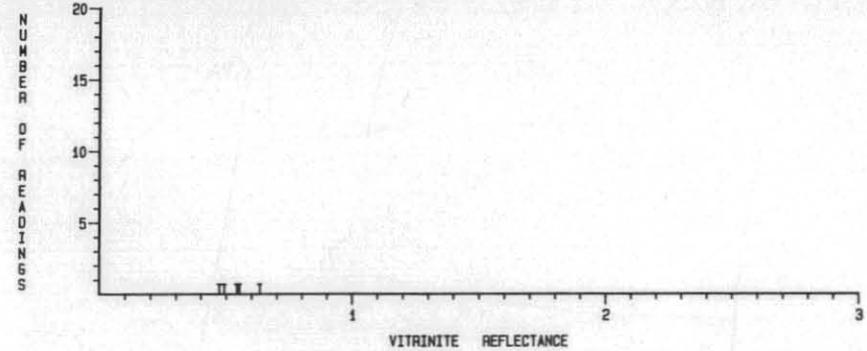
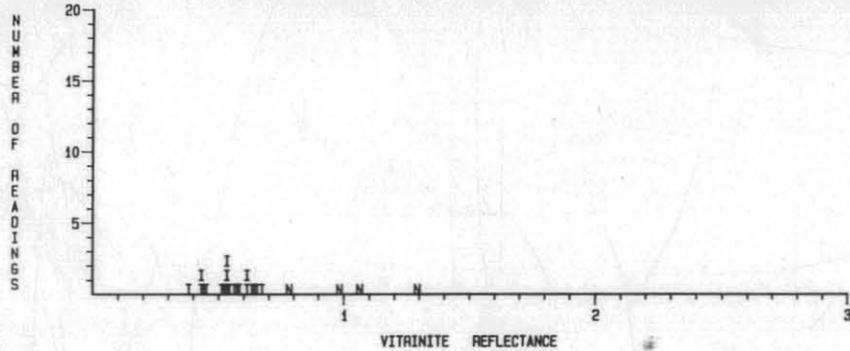
VITRINITE REFLECTANCE AND COAL MACERAL IDENTIFICATION

CLIENT NAME : BRIDGE OIL LTD. DATE : OCTOBER 1985 WELL NAME : DURROON 1  
 DEPTH OR SAMPLE No : 4540 Feet SAMPLE TYPE : Cuttings  
 (Total No. of Readings = 24) 0.38 0.43 0.43 0.44 0.45 0.51 0.52 0.53 0.53 0.54 0.56 0.57 0.58 0.61 0.61 0.63  
 0.64 0.65 0.67 0.78 0.98 1.06 1.29

CLIENT NAME : BRIDGE OIL LTD. DATE : OCTOBER 1985 WELL NAME : DURROON 1  
 DEPTH OR SAMPLE No : 4780 Feet SAMPLE TYPE : Cuttings  
 (Total No. of Readings = 5) 0.47 0.48 0.54 0.55 0.63

VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	83.3	20	0.54	0.38	0.67	0.08	INDIGENOUS (I)	0.00	33.00	11.00	56.00
2	16.7	4	1.03	0.78	1.29	0.21	INERTINITE (N)	No data	No data	No data	No data

VITRINITE REFLECTANCE						MACERAL IDENTIFICATION					
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	5	0.54	0.47	0.63	0.06	INDIGENOUS (I)	0.00	85.00	7.00	8.00

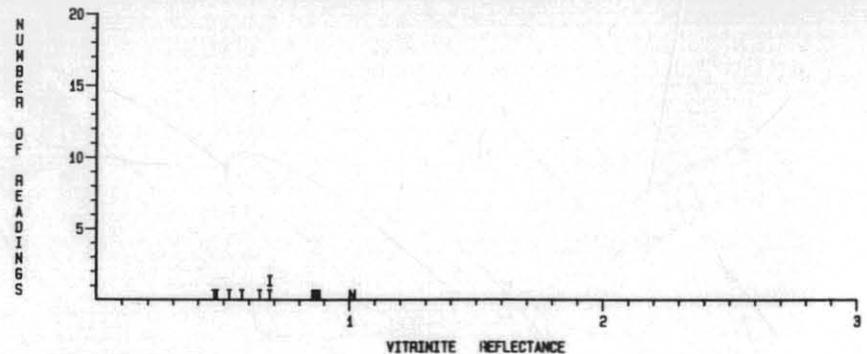
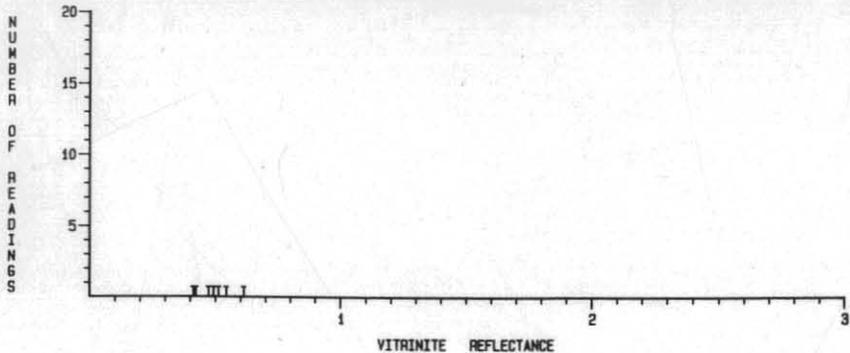


CLIENT NAME : BRIDGE OIL LTD. DATE : OCTOBER 1985 WELL NAME : DURROON 1  
 DEPTH OR SAMPLE No : 4680 Feet SAMPLE TYPE : Cuttings  
 (Total No. of Readings = 7) 0.41 0.42 0.47 0.48 0.51 0.54 0.61

CLIENT NAME : BRIDGE OIL LTD. DATE : OCTOBER 1985 WELL NAME : DURROON 1  
 DEPTH OR SAMPLE No : 4900 Feet SAMPLE TYPE : Cuttings  
 (Total No. of Readings = 10) 0.46 0.47 0.52 0.57 0.64 0.68 0.68 0.68 0.87 1.01

VITRINITE REFLECTANCE							MACERAL IDENTIFICATION				
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	100	7	0.49	0.41	0.61	0.07	INDIGENOUS (I)	0.00	23.00	24.00	53.00

VITRINITE REFLECTANCE						MACERAL IDENTIFICATION					
POPULATION Number	%	No. of Readings	Mean Ro (%)	Min. Ro (%)	Max. Ro (%)	STD. Dev. (%)	Comments	% Alginite	% Exinite	% Vitrinite	% Inertinite
1	70	7	0.57	0.46	0.68	0.09	INDIGENOUS (I)	0.00	24.00	4.00	72.00
2	30	3	0.91	0.68	1.01	0.08	INERTINITE (N)	No data	No data	No data	No data



5 cm

365046



TABLE 1

## ROCK-EVAL PYROLYSIS DATA (one run)

WELLNAME = DURROON 1

DATE OF JOB = NOVEMBER 1985

DEPTH(ft)	TMAX	S1	S2	S3	S1+S2	S2/S3	PI	PC	TOC	HI	OI
4540.0	nd	nd	nd	nd	nd	nd	nd	nd	0.92	nd	nd
4630.0	434	0.09	0.62	3.31	0.71	0.19	0.13	0.06	1.46	42	226
4660.0	434	0.07	0.44	2.46	0.51	0.18	0.14	0.04	1.80	24	136
4720.0	nd	nd	nd	nd	nd	nd	nd	nd	1.26	nd	nd
4780.0	434	0.11	1.05	2.45	1.16	0.43	0.09	0.10	1.64	64	149
4840.0	nd	nd	nd	nd	nd	nd	nd	nd	1.55	nd	nd
4900.0	435	0.06	0.64	2.99	0.70	0.21	0.09	0.06	1.69	37	176
4960.0	436	0.08	0.49	3.47	0.57	0.14	0.14	0.05	1.64	29	211
5020.0	nd	nd	nd	nd	nd	nd	nd	nd	1.36	nd	nd
5040.0	nd	nd	nd	nd	nd	nd	nd	nd	1.30	nd	nd
5700.0	440	0.11	0.87	0.87	0.98	1.00	0.11	0.08	1.13	76	76
6010.0	438	0.24	1.38	1.49	1.62	0.93	0.15	0.13	1.26	109	118
6250.0	438	0.30	1.97	0.91	2.27	2.16	0.13	0.19	1.51	130	60
6490.0	nd	nd	nd	nd	nd	nd	nd	nd	0.37	nd	nd

TMAX = Max. temperature S2  
 S1+S2 = Potential yield  
 PC = Pyrolysable carbon  
 OI = Oxygen Index

S1 = Volatile hydrocarbons (HC)  
 S3 = Organic carbon dioxide  
 TOC = Total organic carbon  
 nd = no data

S2 = HC generating potential  
 PI = Production index  
 HI = Hydrogen index

## Core Description

TABLE 2

## DURROON NO. 1

K.K. No.	Depth (ft)	$\bar{R}_V$ max	Range	N	Exinite Fluorescence (Remarks)
LOWER CRETACEOUS					
x3221	4540 Ctgs	0.54	0.38-0.67	20	Sparse sporinite and rare liptodetrinite, yellow to orange. (Claystone>sandstone>carbonate>calcareous claystone. Dom common, I>E>V. Inertinite and exinite sparse, vitrinite rare. Iron oxides abundant. Inorganic mud additive rare. Pyrite abundant.)
CRETACEOUS					
x3222	4660 Ctgs	0.49	0.41-0.61	7	Rare sporinite and liptodetrinite, yellow to orange. (Claystone>sandstone>calcareous siltstone>coal. Coal rare, vitrinite. Dom sparse, I>E>V. Inertinite sparse, exinite and vitrinite rare. Iron oxides abundant. Pyrite abundant.)
x3223	4780 Ctgs	0.54	0.47-0.63	5	Common sporinite and sparse liptodetrinite, yellow to dull orange, rare cutinite, yellow to orange. (Claystone>sandstone>carbonate. Dom common, E>I>V. Exinite common, Inertinite and vitrinite rare. Iron oxides common. Pyrite abundant.)
x3224	4900 Ctgs	0.57	0.46-0.68	7	Sparse sporinite, yellow to dull orange, rare <u>Botryococcus</u> -type telalginite, yellow, rare liptodetrinite, yellow orange to dull orange. (Claystone>sandstone. Dom common, I>E>V. Inertinite common, exinite sparse, vitrinite rare. Iron oxides abundant. Pyrite abundant.)
x3225	5020 Ctgs	0.58	0.44-0.74	23	Rare sporinite and liptodetrinite, yellow orange to orange. (Sandy claystone>carbonate>sandstone. Dom common, I>V>E. Inertinite common, vitrinite sparse, exinite rare. Iron oxides abundant. Sample heat altered. Pyrite abundant.)

THEORY AND METHODS

This section details a series of geochemical methods which are commonly used in our laboratory, including those used to obtain the data presented in this report. Where applicable, the discussion is accompanied by a summary of the general theory used to interpret the data generated by each method.

1. SEDIMENTARY GAS ANALYSISa) Headspace Analysis

Headspace analysis is carried out using sealed containers (usually tinned cans) of wet cuttings. The containers are approximately three quarters filled with the cuttings and water to leave an appreciable headspace into which volatile hydrocarbons contained in the cuttings diffuse.

After covering about 1cm<sup>2</sup> of the container lid with silicone and allowing the silicone to dry, the procedure involves placing a small hole in the lid through the silicone, then sampling an aliquot of the headspace gas with a gas injection syringe, and finally gas chromatographing this sample of gas under the following conditions: instrument = Shimadzu GC-8APF; column = 6' x 1/8" Chromosorb 102; column temperature = 110 Deg. C; carrier gas = nitrogen at 23mls/min; injector temperature = 120 Deg. C.; analysis cycle = C1-C4 components are flushed from the column in the forward direction and then the C5-C7 compounds are removed from the column by backflushing.

The integrated areas of peaks representing each of the C1-C7 components of the headspace gas are compared to the areas of corresponding components of a standard gas of known composition. The calculated amount of each component in the sample gas is adjusted for the total headspace volume and reported as ppm (parts of gas per million parts of sediment by volume).

Data from headspace analysis is commonly used to identify the zone of oil generation by plotting gas wetness (C2-C4/C1-C4) expressed as a % against sediment burial depth. Gas containing appreciable quantities of C2-C4 components, termed wet gas (Fuex, 1977), is generally considered to be gas associated with oil generation. In addition, the ratio of isomeric butanes can sometimes be used for assessment of sediment maturity (Alexander et. al., 1981). The amount of gas in sediments can be used to identify zones of significant gas generation and out-of-place gas (LeTran et. al., 1975).

b) Cuttings Gas Analysis

This analysis is the same as Headspace Analysis with the exception that instead of analysing the gas in the container headspace, a known volume of the wet cuttings are transferred to the blender bowl of a Kenwood electronic blender with the lid modified to incorporate a septum, water at 75 Deg. C is added to leave a headspace of 160ml, and the mixture is blended at maximum speed for 2 minutes. Following a 2 minute settling period 1ml of the blending bowl headspace gas is analysed as described in section 1a.

It is recommended that for the most meaningful gas data both headspace and cuttings gas analysis are carried out. In such cases we provide tabulations of the headspace, gas, and combined headspace/cuttings gas data. Normally, the combined data is used for plotting purposes.

## 2. SAMPLE PREPARATION

a) Cuttings

Cuttings samples are inspected by our qualified geological staff and then water washed according to the drilling mud content and lithology. In special cases (e.g. diesel contamination) it is necessary to lightly solvent wash samples. After washing, the samples are air dried, either sieved or picked free of cavings, and crushed to 0.1mm using a ring pulveriser.

b) Sidewall Cores

Sidewall samples are freed of mud cake and any other visible contaminants, and are also inspected for lithologic homogeneity. For homogeneous samples, the minimum amount of material required for the requested analyses is air dried and handcrushed to 0.1mm. For non-homogeneous samples, the whole sample is air dried and handcrushed to 0.1mm.

c) Conventional Core and Outcrop Samples

These sample types are firstly inspected for visible contaminants, and where applicable, are freed of these contaminants to the best of our ability. Commonly, the surface of conventional core and outcrop samples are lightly solvent washed. The samples are then crushed to approximately 1/8" chips using a jaw crusher, air dried, and finally further crushed to 0.1mm using a ring pulveriser.

d) Petroleum/Aqueous Mixtures

The most common sample type in this category are RFT tests containing oil, water and mud. The mixture is placed in a separation funnel and allowed to stand for several hours which enables the petroleum and water/mud fractions to separate. The neat petroleum is isolated by removal of the lower layer (water/mud) from the funnel. To remove the last traces of water and mud, the neat petroleum is centrifuged at moderate speed.

When the volume of petroleum accounts for only a very small part of the sample the method above is unsatisfactory and the petroleum is solvent extracted from the mixture with dichloromethane. The petroleum is recovered by careful evaporation of the solvent from the organic layer.

## 3. TOTAL ORGANIC CARBON DETERMINATION

The total organic carbon value (TOC) is determined on the unextracted sediment sample. The value is determined by treating a known weight of sediment with hot dilute HCl for 1 hour to remove carbonate minerals, and then heating the residue to 1700 Deg. C (Leco Induction Furnace CS-044) in an atmosphere of pure oxygen. The carbon dioxide produced is transferred to an infra-red detector which has been calibrated with a series of standards, and the microprocessor of the Leco unit then automatically calculates the % TOC in the sample. To ensure reliable data a standard is run after every 10 samples, regular sample repeats are carried out, and at least one blank determination is carried out for each batch of samples.

The following scales are normally used for source rock classification based on % TOC data:

<u>Classification</u>	<u>Clastics</u>	<u>Carbonates</u>
Poor	0.00 - 0.50	0.00 - 0.25
Fair	0.50 - 1.00	0.25 - 0.50
Good	1.00 - 2.00	0.50 - 1.00
Very Good	2.00 - 4.00	1.00 - 2.00
Excellent	> 4.00	> 2.00

#### 4. ROCK-EVAL PYROLYSIS

Although a preliminary source rock classification is made using TOC data a more accurate assessment accounting for organic source type and maturity is made by pyrolysis analysis. Two types of Rock-Eval pyrolysis services are offered: "one run" which involves pyrolysis of the crushed but otherwise untreated sediment and "two run" which involves pyrolysis of both the crushed, untreated sediment and sediment which has been rendered free of carbonate minerals by treatment with hot dilute HCl. The two run service offers considerably more reliable S3 data.

The method involves accurately weighing approximately 100mg of the sample into a sintered steel crucible and subjecting it to the following pyrolysis cycle:

- Stage (i) - Sample purged with helium for 3.5 minutes in unheated part of pyrolysis furnace;
- Stage (ii) - Sample heated at 300 Deg. C for 3 minutes to liberate free petroleum (S1 peak);
- Stage (iii) - Sample heated from 300 Deg. C to 550 Deg. C at 25 Deg. C/minute to produce petroleum from kerogen (S2 peak). The furnace is maintained at 550 Deg. C for one minute. Carbon dioxide produced during this pyrolysis up to 390 Deg. C in the case of "one run" and 550 Deg. C for "two run" is absorbed on a molecular sieve trap;
- Stage (iv) - During the cool down period the carbon dioxide produced during pyrolysis is measured (S3 peak).

The units used for Rock-Eval data are as follows:

S1, S2, S3 = kg/tonne or mg/g of rock

Tmax = Deg. C

Hydrogen Index =  $\frac{S2}{TOC} \times \frac{100}{1}$

Oxygen Index =  $\frac{S3}{TOC} \times \frac{100}{1}$

Rock-Eval data is most commonly used in the following manner:

- (i) S1 - indicates the level of oil and or/gas already generated by the sample according to the following scale:

<u>SI (mg/g or kg/tonne)</u>	<u>Classification</u>
0.00 - 0.20	Poor
0.20 - 0.40	Fair
0.40 - 0.80	Good
0.80 - 1.60	Very Good
> 1.60	Excellent

- (ii) S1+S2 - referred to as the genetic potential this parameter is used for source rock classification according to the following criteria:

<u>S1+S2 (mg/g or kg/tonne)</u>	<u>Classification</u>
0.00 - 1.00	Poor
1.00 - 2.00	Marginal
2.00 - 6.00	Moderate
6.00 - 10.00	Good
10.00 - 20.00	Very Good
> 20.00	Excellent

- (iii) S1/(S1+S2)- this parameter is the production index (PI) which is a measure of the level of maturity of the sample. For oil prone sediments, values less than 0.1 are indicative of immaturity, the values increase from 0.1 to 0.4 over the oil window and values greater than 0.4 represent over maturity. For gas prone sediments, the PI data shows a relatively smaller change with increasing maturity.

- (iv) Tmax - the temperature corresponding to the S2 maxima. This temperature increases with increasingly mature sediments. Values less than 430 Deg. C are indicative of immaturity while values from 430/435 to 460 Deg. C represent the maturity range of the oil window. Tmax values greater than 460 Deg. C are indicative of over maturity.

- (v) HI, OI - the hydrogen ((S2 x 100)/TOC) and oxygen ((S3 x 100)/TOC) indices when plotted against one another provide information about the type of kerogen contained in the sample and the maturity of the sample. Both parameters decrease in value with increasing maturity. Samples with large HI and low OI are dominantly oil prone and conversely samples with low HI and large OI are at best gas prone.

## 5. EXTRACTION OF SEDIMENT SAMPLES

Crushed sediment (maximum of 250g) and 300mls of purified dichloromethane are placed in a 500ml conical flask and are then blended for ten minutes with a Janke and Kunkel Ultra-Turrax T45/2G high efficiency disperser. After a ten minute settling period the solvent is separated from the sediment using a large Buchner filtration system. The extract is recovered by careful evaporation of the solvent on a steam bath and weighed. The weight of extract is used to calculate % EOM and ppm EOM using the following formulae:

$$\% \text{ EOM} = \frac{\text{Wt EOM}}{\text{Wt Sediment Extracted (g)}} \times \frac{100}{1}$$

$$\text{ppm EOM} = \frac{\text{Wt EOM (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The following scale is used to classify the source rock richness of samples based on C12+ extractables:

<u>Classification</u>	<u>ppm Total Extract</u>
Poor	0 - 500
Fair	500 - 1000
Good	1000 - 2000
Very Good	2000 - 4000
Excellent	> 4000

#### 6. SEPARATION OF PETROLEUM INTO CONSTITUENT FRACTIONS

Sediment extracts and crude oil or condensate samples are separated into saturate, aromatic and NSO (asphaltenes plus resins) fractions by medium pressure liquid chromatography (MPLC). That part of the petroleum which is soluble in pentane is applied to the MPLC system via a sample loop and is then pumped using pentane to a partially activated silicic acid pre-column which prevents further movement of the non-hydrocarbon compounds. The hydrocarbon components are pumped further to a Merck Si60 column where the saturate fraction is obtained by forward flushing and the aromatic fraction is recovered by reverse flushing. This separation procedure is monitored using a refractive index detector. To complete the separation the pre-column is removed from the MPLC system and flushed with dichloromethane: methanol (1:10). This non-hydrocarbon fraction is combined with the pentane insoluble material which is not applied to the MPLC system, and is labelled as the NSO fraction. The neat fractions are recovered by careful removal of the solvent by distillation and are weighed.

The weight of each fraction is used to calculate the % of each fraction in the sediment according to the following formulas:

$$\% \text{ Fraction} = \frac{\text{Wt Fraction}}{\text{Wt all Fractions}} \times \frac{100}{1}$$

$$\text{ppm Fraction} = \frac{\text{Wt Fraction (mg)}}{\text{Wt Sediment Extracted (kg)}}$$

The ppm hydrocarbon (saturates and aromatics) and ppm saturate values can be used to classify source rock richness and oil source potential respectively according to the following criteria:

<u>Classification</u>	<u>ppm Hydrocarbon</u>	<u>ppm Saturates</u>
Poor	0 - 300	0 - 200
Fair	300 - 600	200 - 400
Good	600 - 1200	400 - 800
Very Good	1200 - 2400	800 - 1600
Excellent	> 2400	> 1600

The composition of the extracts can also provide information about their levels of maturity and/or source type (LeTran et. al., 1974; Philippi, 1974). Generally, marine extracts have relatively low concentrations of saturated and NSO compounds at low levels of maturity, but these concentrations increase with increased maturation. Terrestrially derived organic matter often has a low level of saturates and large amount of aromatic and NSO compounds irrespective of the level of maturity.

N.B. If requested by a client the NSO fraction is separated into asphaltenes and resins by conventional methods.

#### 7. EXTRACTABLE/TOTAL ORGANIC CARBON RATIOS

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) are determined from the appropriate data. The EOM(mg)/TOC(g) ratio can be used as a maturation indicator, especially if the parameter is plotted against depth for a given sedimentary sequence. In an absolute sense it is less reliable as a maturation indicator, although previous work (Tissot et. al., 1971; LeTran et. al., 1974) suggests that the following criteria can be used to determine maturity with this parameter.

< 50	Low maturity
50 - 100	Moderate maturity
> 100	High maturity

The ratios of EOM(mg)/TOC(g) and SAT(mg)/TOC(g) can be used collectively to provide information about source type. For example, if EOM(mg)/TOC(g) is > 100, suggesting a high level of maturity, but the SAT(mg)/TOC(g) < 20 it is very likely that the organic matter is gas prone. Conversely, the same EOM(mg)/TOC(g) value with a SAT(mg)/TOC(g) value > 40 suggests oil prone source type.

#### 8. PYROLYSIS GAS CHROMATOGRAPHY

Pyrolysis-gas chromatography (PGC) incorporates a Chemical Data System Pyroprobe 150 flash pyrolysis unit interfaced with a capillary gas chromatograph. A sample (5-10mg) of extracted sediment is placed in a quartz tube inside the element coil of the pyrolysis probe and is then heated to 610 Deg. C in a few milliseconds, and is maintained at this temperature for 20 seconds. Products generated from the pyrolysis are swept onto the bonded phase capillary column of the gas chromatograph and are chromatographed from -20 Deg. C (isothermal for two minutes) to 280 Deg. C at 4 Deg. C/minute. The product distribution is dominated by the nature of the kerogen from which it is derived.

#### 9. C12+ GAS CHROMATOGRAPHY

C12+ gas chromatography is commonly carried out on the saturate fraction but in certain instances is carried out on neat oil, condensate or extract. The analysis is carried out under the following conditions: instrument = Shimadzu GC-9A; column = 50m x 0.2mm ID OV101 vitreous silica; column temperature = programmed from 60 Deg. C

to 280 Deg. C at 4 Deg. C/min; injection system = Grob splitless using a 30 second dump time and split ratio of 25:1, carrier gas = hydrogen at 2mls/min; sample = 1  $\mu$ l of 0.5% soln in pentane.

The following information is commonly obtained from C12+ gas chromatographic analysis:

(a) n-Alkane Distribution - The C12-C31 n-alkane distribution is determined from the area under peaks representing each of these n-alkanes. This distribution can yield information about both the level of maturity and the source type (LeTran et. al., 1974).

(b) Carbon Preference Index - Two values are determined:

$$\text{CPI (1)} = \frac{(\text{C23} + \text{C25} + \text{C27} + \text{C29}) \text{ Wt\%} + (\text{C25} + \text{C27} + \text{C29} + \text{C31}) \text{ Wt\%}}{2 \times (\text{C24} + \text{C26} + \text{C28} + \text{C30}) \text{ Wt\%}}$$

$$\text{CPI (2)} = \frac{(\text{C23} + \text{C25} + \text{C27}) \text{ Wt\%} + (\text{C25} + \text{C27} + \text{C29}) \text{ Wt\%}}{2 \times (\text{C24} + \text{C26} + \text{C28}) \text{ Wt\%}}$$

The CPI is believed to be a function of both the level of maturity (Cooper and Bray, 1963; Scalan and Smith, 1970) and the source type (Tissot and Welte, 1978). Marine extracts tend to have values close to 1.0 irrespective of maturity whereas values for terrestrial extracts decrease with maturity from values as high as 20 but do not usually reach a value of 1.0

(c) (C21+C22)/(C28+C29) - This parameter provides information about the source of the organic matter (Philippi, 1974). Generally, terrestrial source material gives values <1.2 whereas an aquatic source material results in values >1.5.

(d) Pristane/Phytane Ratio - This value was determined from the areas of peaks representing these compounds. The ratio renders information about the depositional environment according to the following scale (Powell and McKirdy, 1975):

< 3.0	Relatively reducing depositional environment
3.0-4.5	Reducing/oxidizing depositional environment
>4.5	Relatively oxidizing depositional environment

(e) Pristane/n-C17 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value can provide information about both the depositional environment and the level of maturation (Lijmbach, 1975). Very immature crude oil has a pristane/n-C17 ratio >1.0, irrespective of the depositional environment. However, the following classification can be applied to mature crude oil:

<0.5	Open water depositional environment
0.5-1.0	Mixed depositional environment
>1.0	Peat-swamp depositional environment

In the case of sediment extracts these values are significantly higher and the following classification is used:

<1.0	Open water depositional environment
1.0-1.5	Mixed depositional environment
>1.5	Peat-swamp depositional environment

- (f) Phytane/n-C18 Ratio - This ratio was determined from the areas of peaks representing these compounds. The value usually only provides information about the level of maturity of petroleum. The value decreases with increased maturation.
- (g) Relative Amounts of n-Alkanes and Naphthenes - Since n-alkanes and naphthenes are the two dominant classes of compounds in the saturate fraction, a semi-quantitative estimate of the relative amounts of these compounds can be made from saturate GLC's. This information can be used to assess the degree of maturation and/or the source type of the petroleum (Philippi, 1974; Tissot and Welte, 1978). Very immature petroleum has only small proportions of n-alkanes, but as maturity increases the relative amount of n-alkanes increases. In addition, terrestrial petroleum has a greater proportion of high molecular weight naphthenes than petroleum comprising aquatic source material.

#### 10. API/SPECIFIC GRAVITY

A specific gravity (SG) bottle was accurately weighed, then filled with crude oil at 60 Deg. F and finally reweighed. The weight difference was divided by the weight of an equal volume of water at 60 Deg. F to obtain the specific gravity. The following formula was then used to calculate the API gravity:

$$\text{API Gravity} = \left[ \frac{141.5}{\text{SG (60 Deg. F)}} \right] - 131.5$$

The reported gravity value is the average of duplicate determinations.

#### 11. SULPHUR DETERMINATION

The % sulphur by weight is determined by dissolving 0.5g of the petroleum in 50mls kerosene and then analysing this mixture with an inductively coupled plasma (ICP) instrument which has been calibrated with a series of sulphur standards.

This parameter is influenced by the nature of the source material from which a crude is derived, the depositional environment of the source rocks, and reservoir alteration processes such as bacterial alteration.

#### 12. C1-C31 WHOLE SAMPLE GAS CHROMATOGRAPHY

This method of analysis is normally only applied to oil or condensate samples. The technique provides a "picture" of the sample which shows good resolution of the low, medium and high molecular weight components. Whole sample GC data is considered to be more useful than C12+ saturate fraction GC data for oil or condensate samples.

The analysis is carried out under the same conditions as for the C12+ GC analysis with the following exceptions: column temperature = programmed from -20 Deg. C to 280 Deg. C at 4 Deg. C/min (uses cryogenic mode); injection is carried out in split mode; sample = 0.1 µl of neat petroleum.

C1-C31 analysis data can be used to obtain the same information as that obtained from C12+ GC but further provides detailed compositional data on the C1-C11 fraction and enables calculation of the distillation range of the sample.

### 13. MOLECULAR SIEVE EXTRACTION

This technique is used to isolate the branched/cyclic alkanes from the saturated fraction for gas chromatography/mass spectrometry analysis. A mixture of saturates: 5A molecular sieves: purified benzene in the proportions 1:5:12 by weight is placed in a 100ml round bottom flask and refluxed for 24 hours. After cooling, the sieves are filtered from the liquid phase and are washed with 4 x 10ml aliquots of benzene. The liquid phase plus washing are freed of benzene by distillation yielding the branched/cyclic compounds.

### 14. COMPUTERIZED GAS CHROMATOGRAPHY/MASS SPECTROMETRY (GC/MS)

Gas chromatography/mass spectrometry employs a capillary column gas chromatograph linked in series with a mass spectrometer and data system (GC/MS/DS). As molecules are eluted from the capillary column they are bled into the analyser tube of the mass spectrometer where they are bombarded with high energy electrons and consequently fragment to form several ions each with molecular weights less than that of the parent molecule. The fragmentation pattern is characteristic of the particular molecular type. The spectrum of these ions (referred to as a mass spectrum) is recorded approximately once every second and all of the mass spectra recorded during a GC/MS/DS analysis are memorised by the data system. Since any given class of molecules will breakdown in the analyser type to give one or more characteristic ion fragments of known molecular weight, after a GC/MS/DS analysis it is possible to examine the distribution of compounds within a given class by having the data system reproduce a mass fragmentogram (plot of ion concentration against gas chromatography retention time) representative of the particular class.

GC/MS/DS analyses can be carried out using one of the two following modes of operation:

- (i) Acquire mode - in which all ions in each mass spectrum are memorised by the data system;
- (ii) Selective ion monitoring (SIM) mode - in which only selected ions of interest are memorised by the data system.

At present the sterane/triterpane/bicyclane fraction of petroleum is considered most useful for GC/MS/DS analysis and therefore we commonly use the second of the above mentioned modes of operation and run the following twenty-two ions which are pertinent to the sterane/triterpane/bicucane fraction.

<u>Ion</u>	<u>Molecular Type</u>
177	Demethylated triterpanes
191	Normal triterpanes
205	Methyl triterpanes
163	Specific dethylated triterpanes
356	Parent ion - C26 triterpanes
370	Parent ion - C27 triterpanes
384	Parent ion - C28 triterpanes
398	Parent ion - C29 triterpanes

412	Parent ion - C30 triterpanes
426	Parent ion - C31 triterpanes
183	Isoprenoids
217	Normal steranes
218	Normal steranes
231	4-methylsteranes
259	Diasteranes
358	Parent ion - C26 steranes
372	Parent ion - C27 steranes
386	Parent ion - C28 steranes
400	Parent ion - C29 steranes
414	Parent ion - C30 steranes

GC/MS/DS analysis of the sterane/triterpane/bicyclane fraction can often provide information about the maturity and source type of petroleum and whether it has been affected by micro-organisms. This technique is also often useful for oil:oil and oil:source rock correlation. The following sections indicate which parameters are used to obtain this information and summarize the theory behind their use.

### Maturity

#### (i) Based on Steranes

- (a) The biologically produced  $\alpha\alpha\alpha$  (20R) stereoisomer is converted in sediment to a mixture of the  $\alpha\alpha\alpha$  (20R) and  $\alpha\alpha\alpha$  (20S) compounds. The ratio of  $\alpha\alpha\alpha$  (20S) to  $\alpha\alpha\alpha$  (20R) expressed as a percentage is about 25% at the onset of oil generation and increases almost linearly to a value of about 50% at the peak of oil generation.

#### (ii) Based on Triterpanes

- (a) The C31, C32, C33, C34 and C35 hopanes have the biological configuration at C22. On mild thermal maturation equilibration occurs to produce a 60/40 mixture of S/R. This equilibration occurs before the onset of oil generation.
- (b) The conversion of the biological  $17\beta,21\beta$  hopanes to the corresponding  $17\alpha,21\beta$  and  $17\beta,21\alpha$  compounds is also maturation dependant. For C30 triterpanes the ratio of  $17\beta,21\alpha$  to  $17\alpha,21\beta$  decreases steadily from a value of about 0.4 at the onset of oil generation to a value of about 0.1 at peak oil generation.
- (c) Two of the C27 triterpanes can also be used as maturity indicators. The ratio of  $18\alpha$  (H) trisnorhopane to  $17\alpha$  (H) trisnorhopane increases exponentially with increasing maturity from a value of approximately 0.2 at the onset of oil generation to approximately 1.0 at peak oil generation.
- (d) It is our experience that the ratio of the C27  $18\alpha$  (H) + C27  $17\alpha$  (H) triterpanes to C30  $17\alpha,21\beta$  triterpane is maturity dependent. The ratio decreased from values around 1.0 at the onset of oil generation to a value of approximately 0.4 at peak oil generation. With increasing maturity at levels greater than that equivalent to peak oil generation the ratio

increases steadily to values greater than 3.0.

#### Source Type

(i) Based on Steranes

Algal organic matter contains steranes in which the C27 compounds are more abundant than the C29 compounds. General aquatic organic matter has approximately equivalent amounts of the C27 and C29 compounds while organic matter rich in land-plants usually has a lot more of the C29 steranes.

(ii) Based on Triterpanes

The triterpane components in petroleum can be derived from both bacteria and higher plants. The common bacterial products are the C27-C35 hopanes and moretanes whereas the higher plant triterpanes are compounds other than hopanes or moretanes and are commonly C30 compounds.

(iii) Based on Diasteranes

The diasteranes are not produced biologically but are formed during early diagenesis from sterane precursors. The diasterane ratios

C27(20R)                      C27(20R+20S)

----- and ----- should reflect the nature of the organic

C29(20R)                      C29(20R+20S)

matter in the same manner as that outlined above for the steranes.

#### Biodegradation

It has been observed that in severely biodegraded petroleum the series of normal hopanes are converted to a series of A ring demethylated hopanes and the C29 (20R) sterane is selectively removed. For altered crudes which have not been degraded to this extent the severity of biodegradation can often be gauged by studying the isoprenoid and aromatic fractions. However, this type of investigation extends beyond a standard GC/MS/DS analysis.

#### Correlation

Our present approach to oil:oil or oil:source rock correlation problems is as follows:

- (i) Compare the distribution of compounds in the 123, 177, 191, 205, 217, 218, 231 and 259 mass fragmentograms for an oil or sediment extract to the distribution of compounds in the respective fragmentograms for the other oil(s) or sediment extract(s). It is necessary in this type of comparison to make allowance for small variations due to possible maturity differences.
- (ii) Examine the fragmentograms for peaks or sets of peaks which may represent compounds that are specific to the geological system under investigation. Normal steranes, diasteranes and bacterial hopanes cannot be used for this purpose because they are present in virtually all crude oils and sediment extracts. However, compounds like higher plant triterpanes, bisnorhopane and botryococcane can often prove very useful for this purpose.

## 15. CARBON ISOTOPE ANALYSIS

The measurement is carried out on one or more of the following mixtures; topped oil; saturate fraction; aromatic fraction; NSO fraction. The organic matter is combusted at 860 Deg. C in oxygen and the carbon dioxide formed is purified and transferred to an isotope mass spectrometer. The carbon isotope ratio is measured relative to a standard gas of known isotopic composition. In our case the standard gas is prepared from the NBS No. 22 oil. However, since the isotopic relationship between NBS No. 22 oil and the international reference PDB limestone are known, the values are adjusted to be relative to PDB limestone.

Although carbon isotope data has been commonly used for oil:oil and oil:source rock correlation its most significant application is the identification of the source of gas according to the following criteria (Fuex, 1977):

$\delta^{13}C$ (PDB)	Gas Type
-85 to -58	Biogenic methane
-58 to -40	Wet gas/associated with oil
-40 to -25	Thermal methane

## 16. VITRINITE REFLECTANCE MEASUREMENT

Vitrinite is a coal maceral which responds to increasing levels of thermal maturity. This response can be measured by the percent of light reflected off a polished surface of a vitrinite particle immersed in oil. Reflectance measurements are made on a number (40 if possible) of vitrinite particles in each sample, in order to establish a range and mean for reflectance values. Immature rocks have low reflectance values (0.2% Ro to 0.6% Ro), with mature values ranging from 0.6% Ro to 1.2% Ro. Very mature values are between 1.2 % Ro and 1.8% Ro, while severely altered rocks have reflectances above 1.8% Ro.

Vitrinite reflectance results are best obtained from coals or rocks deposited in environments receiving large influxes of terrestrially-derived organic matter. Unfortunately, these environments are not conducive to the accumulation of large quantities of oil-prone organic mater. Also vitrinite reflectance cannot be performed on rocks older than Devonian Age, due to the absence of land plants in the older geological time periods.

## 17. VISUAL KEROGEN

Visual kerogen assessment is carried out by the coal petrologist and/or the palynologist. In the case of the petrologist the assessment is made in reflected light using the plug prepared for vitrinite reflectance measurement, and reports the relative amounts of alginite, exinite, vitrinite and inertinite particles.

Visual study of kerogen by the palynologist is carried out in transmitted light and can indicate the relative abundance, size and state of preservation of the various recognizable kerogen types and hence indicates the source character of a sedimentary rock. In addition, the colour of the kerogen is related to the thermal maturity of the sediments and is often used as a maturation indicator.

The preparation of slides for visual kerogen assessment by the palynologist firstly involves concentration of the organic matter by removal of the rock matrix using hydrochloric and hydrofluoric acid treatment and heavy liquid separation. The organic concentrate is then mounted on a glass slide using Petropoxy.

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