TRITON-1

Natural Resources and Environment

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PE900594

Organic Petrology

1 Folio No.	2 Referred to	3 Date	4 Clearing Officer's Initials	1 Folio No.	2 Referred to	3 Date	4 Clearing Officer's Initials

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FILE No.

Wellreport No. 2

Organic petrology of the sedimentary sequence at Triton No. 1, Otway Basin.

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Introduction

Twenty three samples from Trition No. 1 were collected for the assessment of the organic matter type and abundance and the maturation level. Fourteen samples (20994 - 21007) are Cuttings from the Triton-1 straight well (T.D. 2803m), nine samples (21008 - 21016) are Cuttings from the Triton-1 side track (T.D. 3545m). The well intersects sediments from the Tertiary and Upper Cretaceous sequence.

Triton 1 is situated in the offshore part of the Otway Basin. The location is shown in Fig. 1.

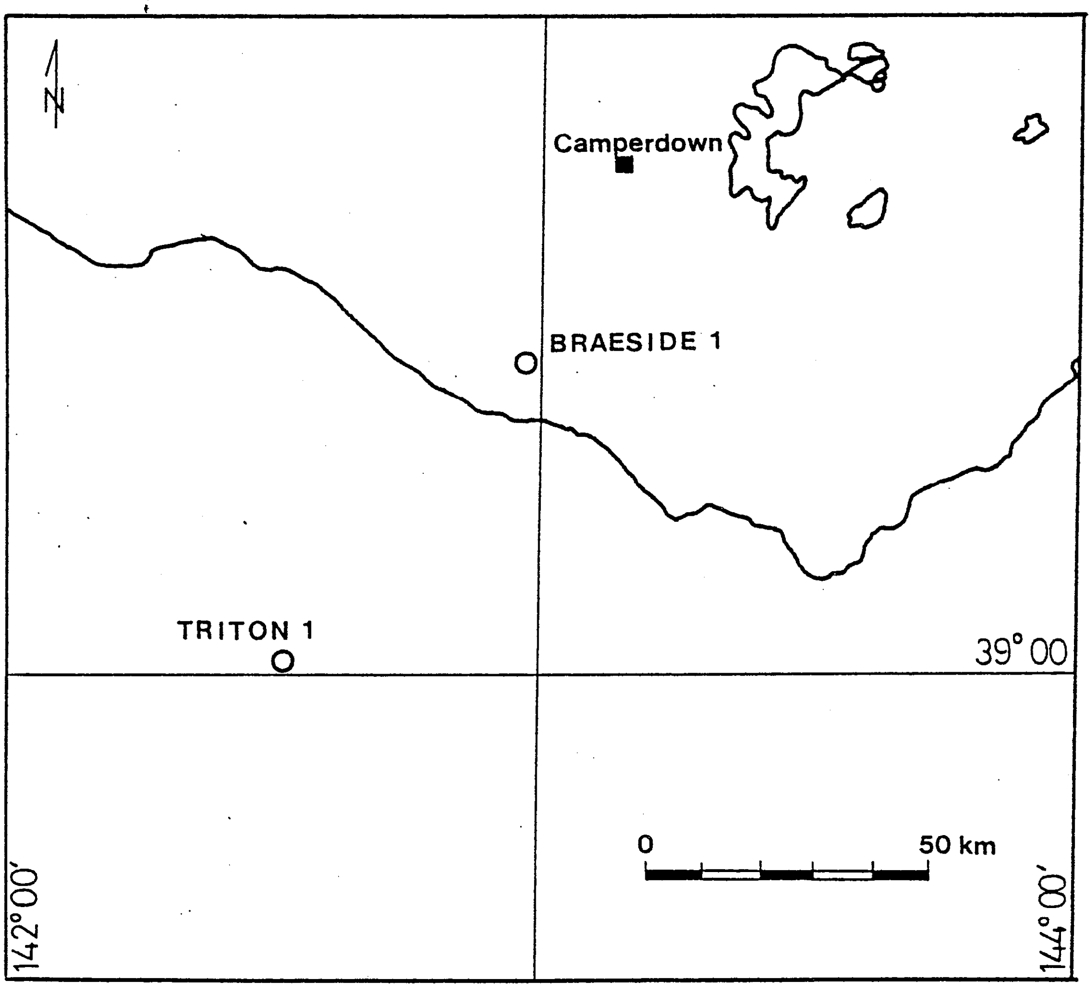


Fig. 1: Location of Triton No. 1.

The samples were mounted in cold-setting polyester resin and polished "as received", so that whole-rock samples rather than concentrates of organic matter were examined. The samples were cut and polished perpendicular to the 'bedding' in the grain mount (the term bedding is here used for the layering associated with the setting of grains in the mounting process).

Vitrinite reflectance measurements were made using immersion oil of refractive index 1.518 (at 546 nm and 23°C) and spinel and garnet standards of 0.42 %, 0.917 % and 1.726 % reflectance. For fluorescence-mode, a 3mm BG 3 excitation filter was used with a TK 400 dichroic mirror and a 490 barrier filter. A Leitz MPV 2 photometer mounted on a Leitz Orthoplan was used for photometric work. A separate Opak illuminator is used for examinations in the fluorescence mode.

The maximum reflectance of vitrinite ($R_V max$) was measured for all occurrences and the mean of the maximum reflectance values ($\bar{R}_V max$) is reported in Table 1 and is used in Figure 6. Additionally, the maximum reflectance of inertinite ($R_I max$) was measured where possible. This gives a control on the vitrinite reflectance and indicates the maturation level of samples where vitrinite is absent (Smith and Cook, 1980).

For the examination of organic matter type and abundance, the percentage of each maceral group occuring as coal, shaly coal and dispersed organic matter (dom) is estimated using comparison charts (Appendix 3) for each grain encountered during a series of traverses of the grain mount. The number of grains examined is normally fifty. The abundance of each maceral group and, for dom, the total dom abundance, is recorded for each grain using a series of abundance categories (Appendix 3). The categories are rare (< 0.1 %), sparse (0.1 % - 0.5 %), common (0.5 % - 2 %), abundant (2.0 % - 10 %) and major (> 10 %), with the categories common, abundant and major approximately corresponding to the geochemical concepts of source-rocks as marginal, good to very good, and prolific, based on T.O.C. values.

Organic Matter Type and Abundance

Organic matter in samples from Triton No. 1 (Figures 2-5) occurs predominantly as sparse to common dispersed organic matter (dom). Inertinite is the major maceral, followed by rare liptinite and vitrinite. The phytoclasts are generally small to very small. A minor occurrence of coal in the form of ?texto-ulminite is restricted to the deeper section of the well.

Very rare liptinite and inertinite are the only macerals present in the Port Campbell Limestone. Liptinite consists of sporinite and dinoflagellates. Abundant foraminifers, shell fragments and framboidal pyrite are characteristic for these samples.

The lithology of the Gellibrand Marl is also dominated by limestone, but some silt- and sandstone is present. Dom is rare in this part of the section and is predominated by inertinite. Liptinite mainly comprises dinoflagellates and some sporinite. Vitrinite is absent from two samples and very rare in the deeper part of the Gellibrand Marl. Foraminifers, shell fragments and framboidal pyrite are also abundant in these samples.

One sample from the Unnamed Sands and Silts shows rare dom, which is dominated by sporinite, cutinite, liptodetrinite and dinoflagellates. Inertinite and vitrinite are very rare in this sample. Common foraminifers and abundant framboidal pyrite are present.

Fourteen samples were collected from the Belfast Mudstone, from both the straight well and the side track. In all samples dom is sparse to common with inertinite as the major maceral, followed by rare liptinite and very rare to rare vitrinite. The vitrinite population in all samples from this unit is generally poorly defined and no vitrinite was found in two samples. The lower part of the inertinite reflectance range includes a considerable amount of oxidised vitrinite. Liptinite mainly comprises phytoplankton (dinoflagellates), sporinite and liptodetrinite. Cutinite occurs only in a few samples and some doubt is attached to the occurrence of rare ?telalginite in three samples (21002/21003/21008). Common to abundant texto-ulminite is present in two samples from this unit (21006/21007) with reflectances lower than the vitrinite population in dispersed organic matter. The lithology of the Belfast Mudstone mainly comprises siltstone, carbonate and claystone with a low percentage of sandstone in a few samples. Shell fragments and other carbonate grains in siltstone are typical for this unit. Abundant framboidal pyrite was observed in all samples from the Belfast Mudstone. Samples from the deeper part of the section contain abundant iron oxides. They mainly occur disseminated in the siltstone, but some individual grains are also present. The presence of abundant iron oxides and common oxidised vitrinite suggests an oxidising environment during the later stages of diagenesis.

Dispersed organic matter in the Waarre Formation is sparse to common with common inertinite as the major maceral and rare vitrinite. A trace of liptinite consisting of dull orange fluorescing liptodetrinite was found in the two uppermost samples from this unit, whereas no fluorescing liptinite was observed in the sample from 3505m. The Waarre Formation mainly consists of sandstone, calcareous siltstone and some carbonate. As in the Belfast Mudstone pyrite is abundant and iron oxides are present, however, they seem to be less abundant in this unit.

Organic matter type and abundance in the sedimentary sequence at Triton No. 1 suggest a marine depositional environment for the whole sequence. The Tertiary sequence consists predominantly of limestone and contains rare dispersed organic matter comprising mainly inertinite and dinoflagellates. The occurrence of foraminifers, shell fragments and framboidal pyrite supports the suggestion of a fully marine environment for this sequence. A nearshore marginally marine environment is assumed for the remainder of the sequence (unnamed sands and silts, Belfast Mudstone, Waarre Formation). The lithology, the sparse to common dom predominated by inertinite with rare liptinite (dinoflagellates, liptodetrinite, sporinite) and rare vitrinite and the presence of foraminifers, shell fragments and framboidal pyrite are here considered to represent a typical marginal marine envrionment.

Fig. 2

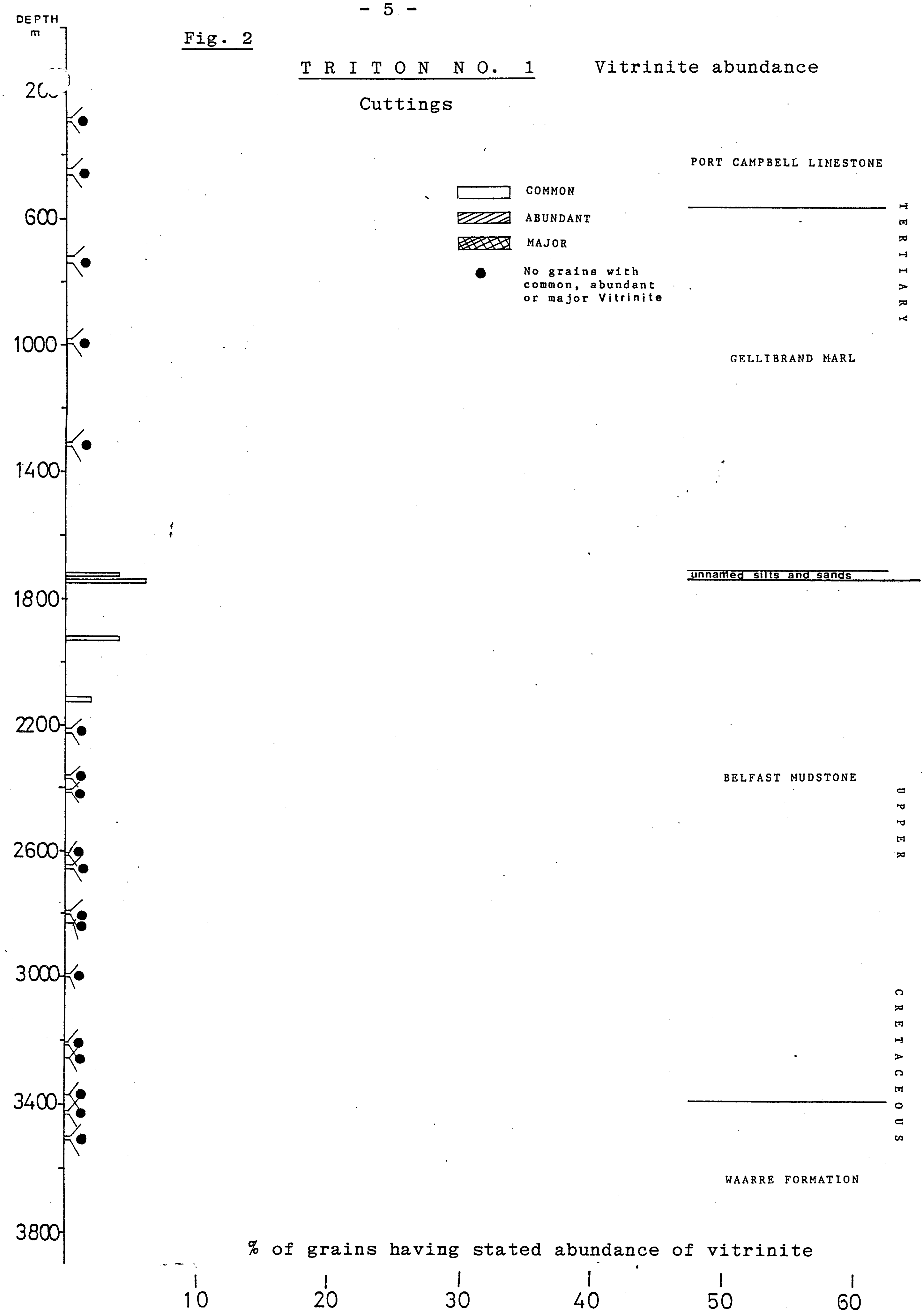

TRITON NO. 1
Vitrinite abundance
Cuttings
DEPTH m
200
600
1000
1400
1800
2200
2600
3000
3400
3800
COMMON
ABUNDANT
MAJOR
No grains with common, abundant or major Vitrinite
PORT CAMPBELL LIMESTONE
GELLIBRAND MARL
unnamed silts and sands
BELFAST MUDSTONE
WAARRE FORMATION
TERTIARY
UPPER CRETACEOUS
% of grains having stated abundance of vitrinite
10
20
30
40
50
60

Fig. 3

TRITON NO. 1 Inertinite abunda e

Cuttings

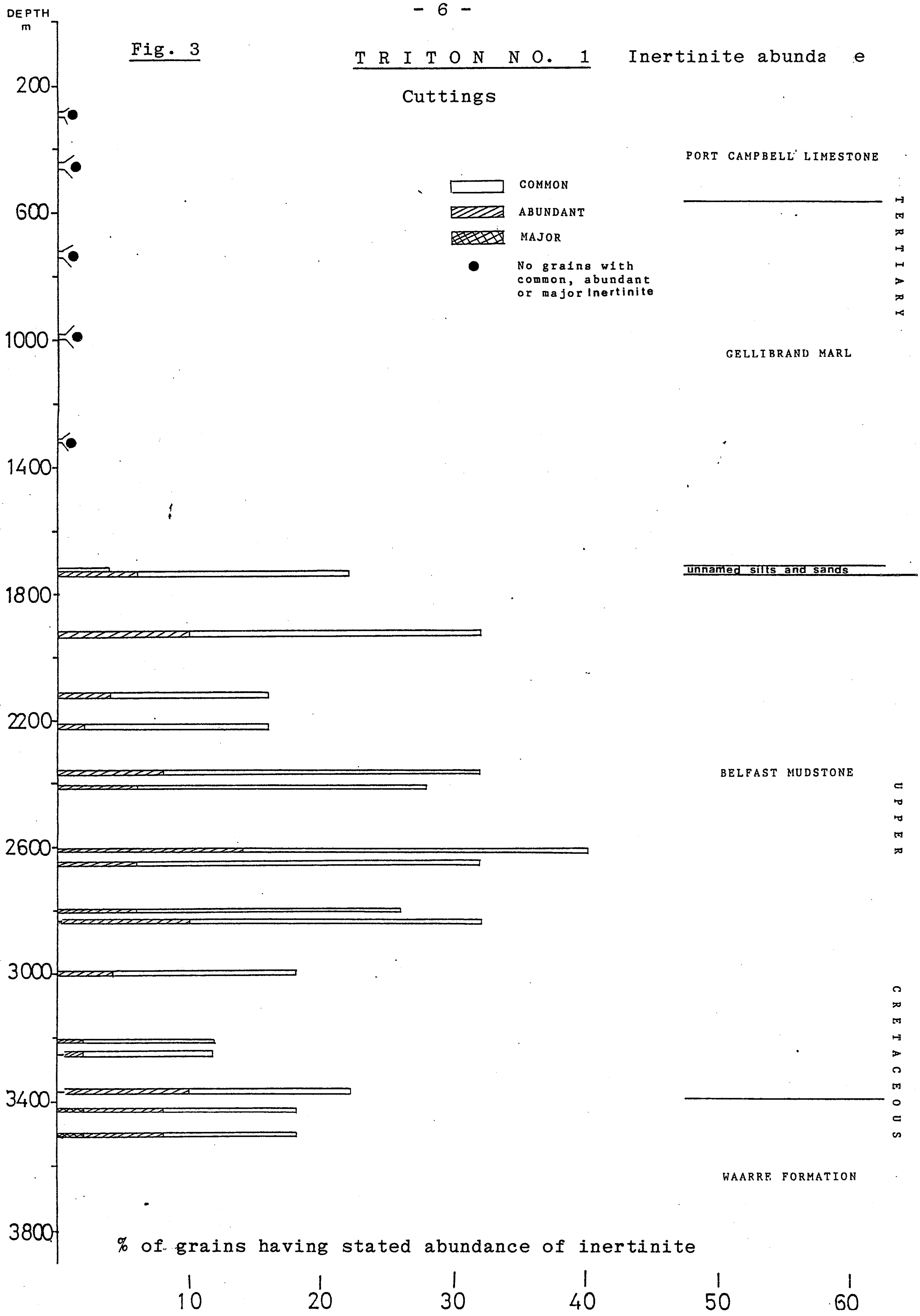


Fig. 4

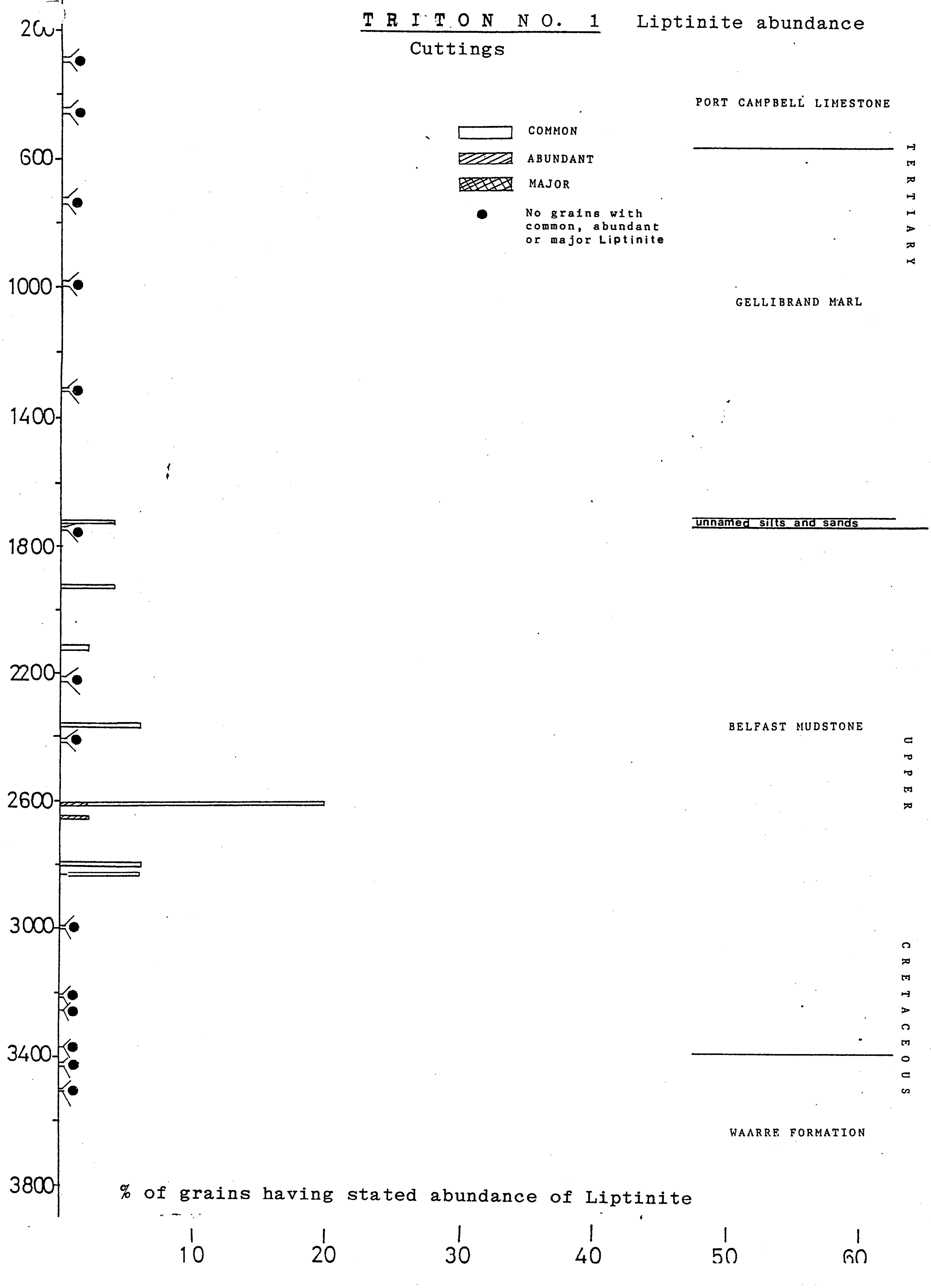
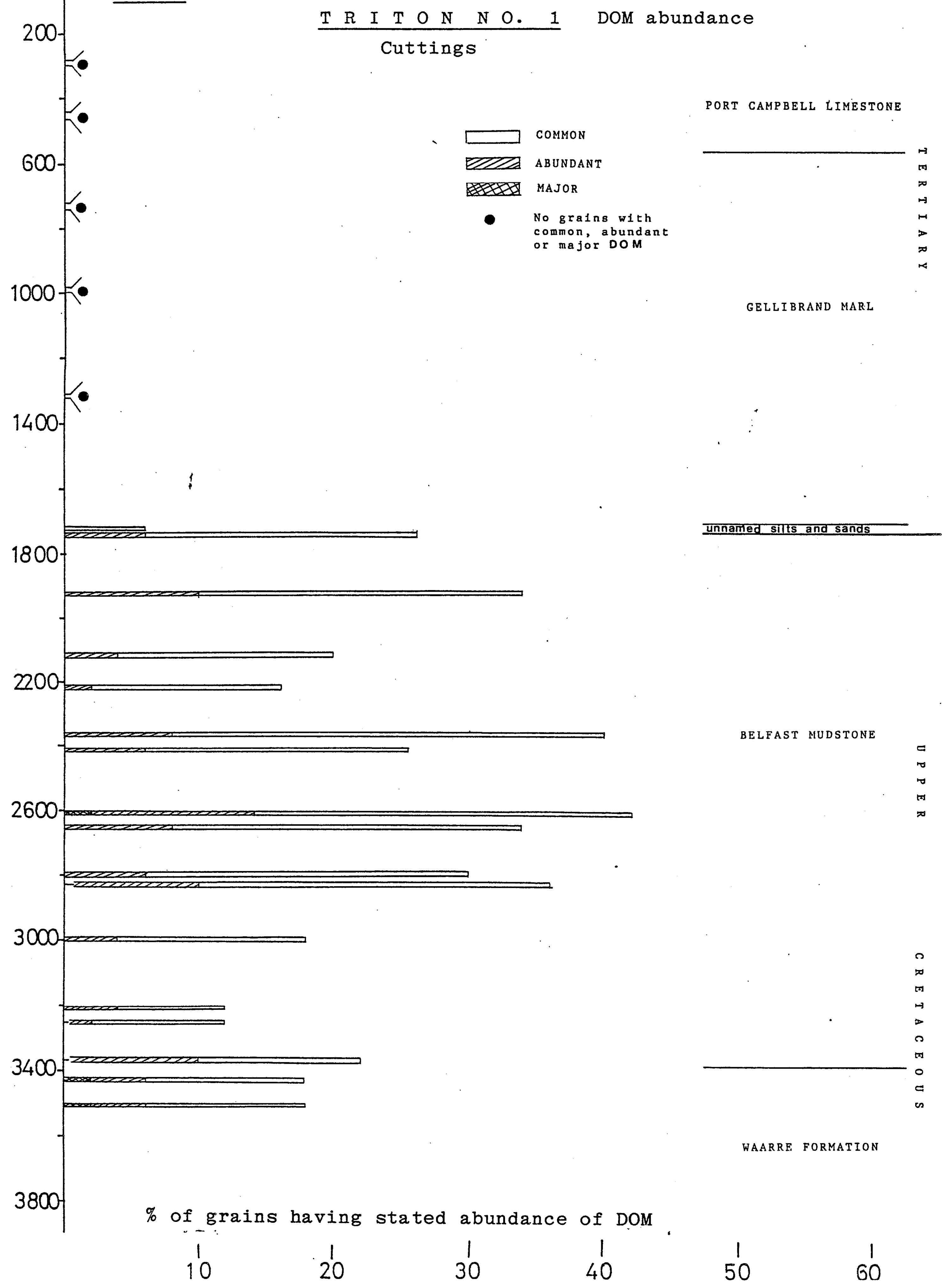

DEPTH m
TRITON NO. 1 Liptinite abundance
Cuttings
COMMON
ABUNDANT
MAJOR
No grains with common, abundant or major Liptinite
PORT CAMPBELL LIMESTONE
TERTIARY
GELLIBRAND MARL
unnamed silts and sands
BELFAST MUDSTONE
UPPER
CRETACEOUS
WAARRE FORMATION
200
600
1000
1400
1800
2200
2600
3000
3400
3800
% of grains having stated abundance of Liptinite
10
20
30
40
50
60

Fig. 5


TRITON NO. 1 DOM abundance
Cuttings
DEPTH m
200
600
1000
1400
1800
2200
2600
3000
3400
3800
COMMON
ABUNDANT
MAJOR
No grains with common, abundant or major DOM
PORT CAMPBELL LIMESTONE
GELLIBRAND MARL
unnamed silts and sands
BELFAST MUDSTONE
WAARRE FORMATION
TERTIARY
UPPER CRETACEOUS
% of grains having stated abundance of DOM
10
20
30
40
50
60

Vitrinite Reflectance and Maturation

The vitrinite population in most Triton-1 samples is poorly defined. Vitrinite phytoclasts are usually very small and only a few measurements could be taken per sample. Vitrinite is absent in a number of samples. Figure 6 shows the mean maximum reflectance and the range of reflectance attributed to each of the horizons sampled. The unbroken line is the most probable trend.

Vitrinite reflectance values show a range of 0.39% $\bar{R}_v$max at 1310m to 1.00% $\bar{R}_v$max at 3510m (Table 1). A considerable amount of oxidised vitrinite is present and is included in the inertinite reflectance range (Table 1) and shows reflectance values from 0.67% to 1.73% $\bar{R}_v$max. Inertinite generally occurs as very small to moderately large phytoclasts and shows a reflectance range of 0.78% $\bar{R}_i$max at 730m to 1.80% $\bar{R}_i$max at 3500m. These inertinite reflectances are relatively low as compared to the corresponding vitrinite reflectances. This is due to the inclusion of reflectances from oxidised vitrinite in the inertinite range. It was not possible to draw a definite line of distinction between inertinite and oxidised vitrinite as the values overlap.

The reflectance gradient increases with depth from 0.20%/km at 0.5% $\bar{R}_v$max to 0.58%/km at 0.9% $\bar{R}_v$max and reaches 0.85%/km (extrapolated) at 1.0% $\bar{R}_v$max (Table 2). The reflectance gradient for the Tertiary sequence is probably much lower than 0.20%/km.

The vitrinite reflectance data indicate that Triton No. 1 entered the oil window at 2070m (0.50% $\bar{R}_v$max) and that the lower part of the Belfast Mudstone and the upper part of the Waarre Formation are probably in the peak zone of oil generation (0.7% to 0.9% $\bar{R}_v$max).

Exinite is present in most samples examined. The exinite macerals fluoresce moderately strongly in the Tertiary sequence and the upper part of the Belfast Mudstone, but the fluorescence intensity gradually decreases with depth to a very weak dull orange fluorescence in the Waarre Formation.

Generally, the Tertiary sequence has vitrinite reflectances (if present) and exinite fluorescence colours indicative of an immature sequence. The vitrinite reflectances and exinite fluorescence colours in the Upper Cretaceous sequence indicate immature to oil mature maturation levels.

Table 1: Maturation data for Triton No. 1

Sample No.	Depth m	Formation	Sample type	$\bar{R}_v$max %	Range	Number	Standard deviation	$\bar{R}_1$max %	Range	Number	Standard deviation
20994	280-295	Pt. Campbell	Ctgs	-	-	-	-	-	-	-	-
20995	440-460	Limestone	"	-	-	-	-	0.97	0.93-1.01	2	0.056
20996	720-740	Gellibrand	"	-	-	-	-	0.78	0.67-0.90	2	0.162
20997	980-1000	Marl	"	-	-	-	-	-	-	-	-
20998	1310-1320	"	"	0.39	0.37-0.41	2	0.028	0.78	0.50-1.27	7	0.313
20999	1720-1725	sands and silts	"	0.42	0.33-0.49	5	0.067	0.88	0.67-1.09	2	0.296
21000	1740-1745	Belfast	"	0.45	0.41-0.48	6	0.023	1.05	0.80-1.45	7	0.253
21001	1920-1930	Mudstone	"	0.45	0.43-0.48	3	0.026	0.93	0.70-1.38	7	0.289
21002	2115-2125	"	"	0.51	0.48-0.55	3	0.035	1.04	0.76-1.56	5	0.324
21003	2215-2225	"	"	0.50	0.47-0.53	3	0.030	1.04	0.71-1.57	10	0.260
21004	2360-2370	"	"	0.53	-	1	-	1.04	0.71-1.42	10	0.235
21005	2410-2420	"	"	-	-	-	-	1.12	0.82-1.73	10	0.277
21006	2645-2655	"	"	0.53	0.52-0.55	3	0.015	1.13	0.87-1.49	10	0.201
21007	2795-2805	"	"	?0.61	0.55-0.67	5	0.047	1.25	0.93-1.63	10	0.225
21008	2605-2610	Belfast	*ST-Ctgs	?0.64	-	1	-	1.13	0.75-1.65	15	0.320
21009	2830	Mudstone	"	0.67	0.61-0.74	6	0.047	1.31	0.80-1.83	12	0.298
21010	2995-3000	"	"	?0.63	-	1	-	1.44	0.95-2.07	10	0.428
21011	3205-3210	"	"	-	-	-	-	1.45	1.20-1.76	6	0.217
21012	3250	"	"	0.86	0.77-0.94	3	0.087	1.52	1.23-2.15	14	0.253
21013	3370	"	"	0.93	0.88-0.97	3	0.049	1.60	1.19-1.93	10	0.250
21014	3420	Waarre	"	0.93	0.80-1.05	4	0.107	1.72	1.18-2.01	7	0.278
21015	3425	Formation	"	0.99	0.86-1.14	6	0.108	1.70	1.35-2.04	10	0.196
21016	3500-3510	"	"	1.00	0.92-1.09	5	0.072	1.80	1.43-2.24	10	0.267

* Side Track

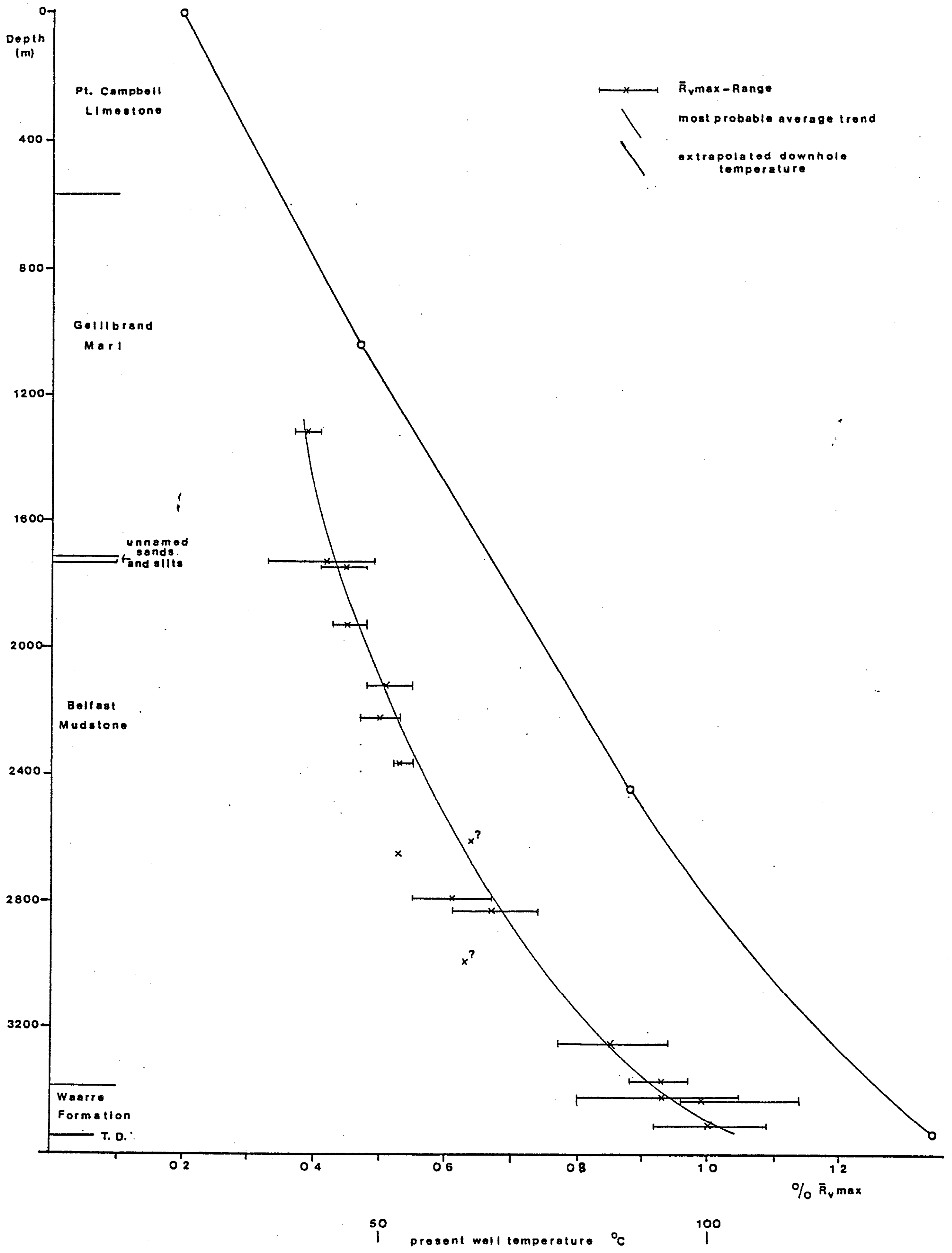


Fig. 6: $\bar{R}_V$max and Range for Triton No. 1

Thermal History

The present geothermal gradient in Triton No. 1 is 32 °C/km. This is slightly higher than for Krambruk 13 (28°C). The temperatures found in Triton No. 1 at given reflectance levels are presented in Table 2, where they are also compared with similar data for wells (Krambruk 13) examined so far. However, this comparison does not take into account varying sample ages.

Present well temperatures in Triton No. 1 are much higher than in Krambruk 13. The relationship $T_{present}$ / $T_{gradthermal}$ suggests the absence of a very early thermal event at Triton 1. Present well temperatures are higher than the gradthermal temperatures in the upper part of the Belfast Mudstone and slightly lower than T_{grad} in the deeper part of the well. The relationship T_{pres} / T_{grad} for Krambruk 13 and Triton 1 is shown in Figure 7. Displacement of the points to the lower right of the line at 45° from the origin indicates a relatively early rise in temperatures whereas displacement above the line indicates a late rise in temperatures (see preliminary draft of Struckmeyer and Cook 1985). The data for Krambruk 13 all lie well below the 45° line which supports the suggestion of an early (Lower Createaceous) rise in temperature for the Otway Ranges area. The data for Triton 1 fall on, or slightly below or above the 45° line, showing that present temperatures in this well tend to be a maximum and that this area is more thermally active at present in relation to maturation processes than the Otway Ranges area at Krambruk 13. The data from Triton 1 resemble those from the Gippsland Basin as described in Smith and Cook (1984), but they are not typical for the Otway Basin. According to Struckmeyer and Cook (1985 in prep.) data for the Otway Basin almost all lie on the lower right side of the 45° line. The data for Triton 1 suggest that the sediments in this well sequence experienced a moderate heating during the Upper Cretaceous period but extremely rapid burial can be assumed for the Upper Tertiary period exposing the sediments to increasingly higher temperatures. This thermal history resembles that from some offshore wells in the Gippsland Basin.

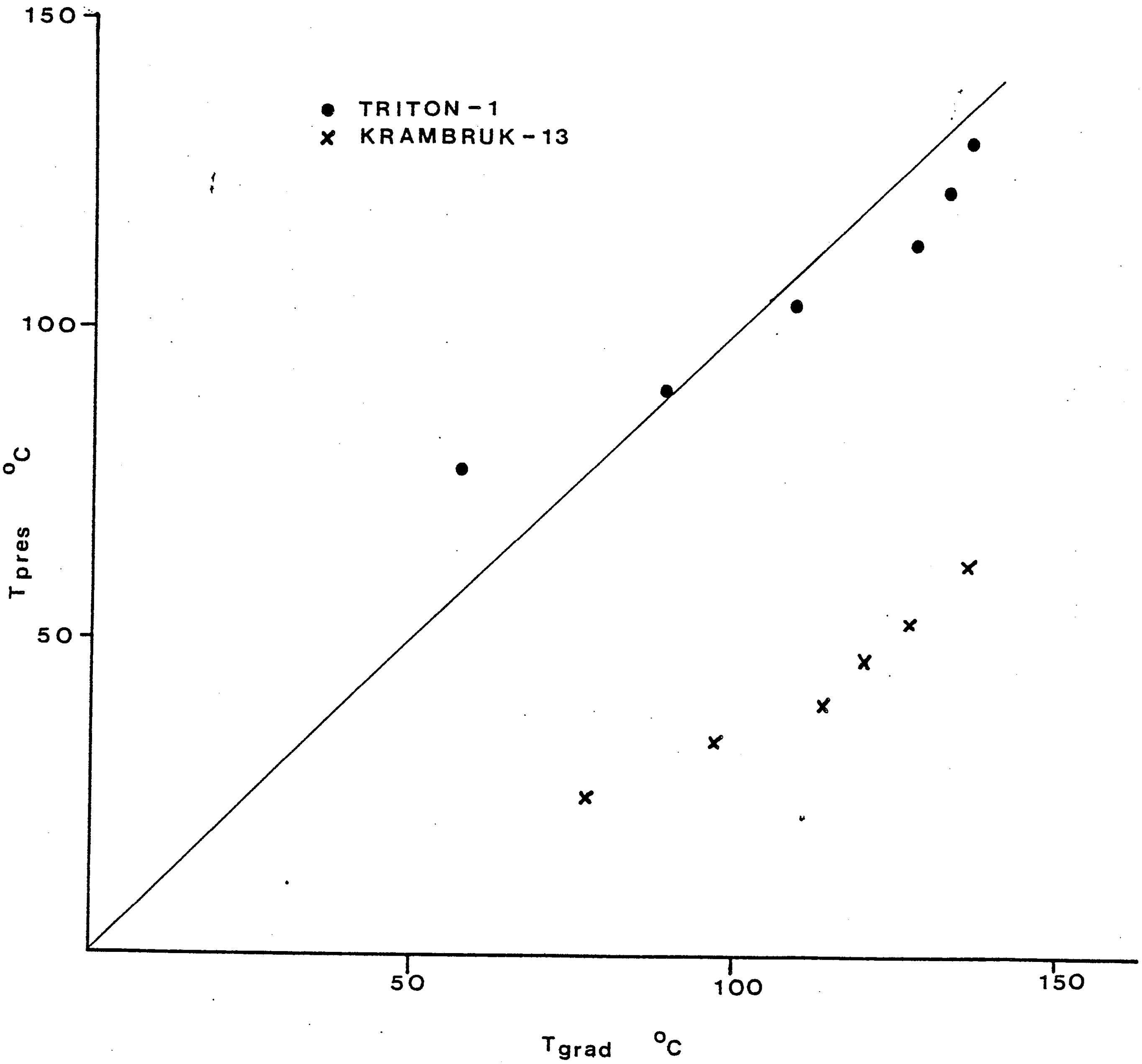


Fig. 7

Table 2: Present well temperatures compared with isothermal and gradthermal model temperatures, and reflectance gradients at given reflectance levels.

Depth (m)	$\bar{R}_v$max %	% $\bar{R}_v$max/km	T_{pres} °C	T_{iso} °C	T_{grad} °C
Triton No. 1					
2070	0.50	0.20	77	40	57
2510	0.60	0.25	90	60	89
2860	0.70	0.32	104	73	109
3140	0.80	0.41	114	85	128
3345	0.90	0.57	123	88	133
3490	1.00	0.85*	131	90	136
Krambruk No. 13					
255	0.60	0.23	25	52	76
615	0.70	0.31	33	65	97
890	0.80	0.40	40	76	114
1110	0.90	0.48	47	80	120
1300	1.00	0.50	53	85	128
1508	1.10	0.57	62	90	136

*extrapolated

Hydrocarbon Source Potential

The hydrocarbon source potential of Triton No. 1 is summarized in Table 3.

The Tertiary sequence (Pt. Campbell Limestone, Gellibrand Marl) has a poor source potential. The maturation levels are very low with vitrinite reflectances too low for significant oil generation. The organic matter content is also very low.

The oil window is reached at about 2000m within the Belfast Mudstone and the deeper part of this unit lies within the peak zone of oil generation. Liptinite is sparse in samples from the Belfast Mudstone and must be considered as a minor source for oil generation. The common inertinite in this sequence is assumed to be a source for hydrocarbons according to the suggestion of Smyth (1983) who considers inertinite to be capable of generating oil. However, the Cooper Basin sequence described by Smyth (1983) usually contains about 20% inertinite, whereas only about 1% inertinite is present in the Belfast Mudstone. The amount of oil generated from the Belfast Mudstone must therefore be considered to be very low.

The Waarre Formation sampled in this well lies within the peak zone of oil generation. Only a trace of liptinite was found in this sequence and the main possible source for hydrocarbons would also be inertinite.

Figure 8 shows the generalized zones of petroleum generation (from Smith and Cook, 1984) in relation to the maturation level. The brackets indicate the range for Triton 1.

The hydrocarbon source potential of Triton 1 is very low to moderate. The assumption of a relatively late rise in temperature and, with that, a late development of the present maturation levels, leads to the conclusion that hydrocarbon generation has occurred during the Tertiary period.

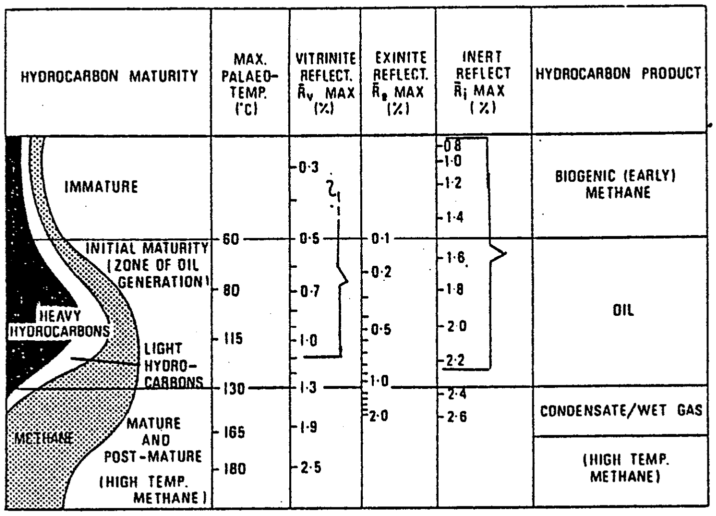


Fig. 8: Generalized zones of petroleum generation (from Smith and Cook, 1984). Range for Triton No. 1.

Table 3: Hydrocarbon source potential of Triton No. 1.

Formation/ Unit	Source Potential	Maturation Level	Probable resultant hydrocarbon generation/migration
Pt. Campbell Limestone	poor	immature	minor biogenic methane
Gellibrand Marl	poor	immature	minor biogenic methane
Belfast Mudstone	low to moderately good	immature to mature	biogenic methane, minor oil near the base
Waarre Formation	moderate	mature	minor oil, probably not significant

References

BOSTICK, N.H., 1983. Time as a factor in thermal metamorphism of phytoclasts (coaly particles). Compte Rendu 7th Congres International Stratigraphique et Geologie Carbonifere, Krefeld, 1971, 2, 183-193.

COOK, A.C. (Ed.), 1982. The origin and petrology of organic matter in coals, oil shales and petroleum source rocks. The University of Wollongong, Wollongong NSW, 106 pp.

KANTSLER, A.J., SMITH, G.C. & COOK, A.C., 1978. Lateral and vertical rank variation: implications for hydrocarbon exploration. APEA JOURNAL, 18, 143-156.

SMITH, G.C., 1982. A review of the Tertiary-Cretaceous tectonic history of the Gippsland Basin and its control on coal measure sedimentation. Australian Coal Geology, 4, 1-38.

SMITH, G.C, & COOK, A.C., 1984. Petroleum occurence in the Gippsland Basin and its relationship to rank and organic matter type. APEA JOURNAL, 24, 196-216.

SMYTH, Michelle, 1983. Nature of source material for hydrocarbons in the Cooper Basin, Australia. Amer. Assoc. Petrol. Geol. Bull., 67 (9), 1422-1428.

STRUCKMEYER, H.I.M. & COOK, A.C., 1985. Source rock and maturation characteristics of the sedimentary sequence in the Otway Basin. (in prep.).

Appendices

Appendix 1: Triton No. 1 - sample description

Appendix 2: grain count estimate chart

Appendix 3: KARWEIL diagram (after Bostick)

Legend: V - vitrinite

I - inertinite

L - liptinite

TRITON No. 1

Sample description

Sample-No.	Depth (m)	
		Pt. Campbell Limestone
20994	280-295 Ctgs	$\bar{R}_v max$ = - Lithology: limestone. Dom absent. Abundant foraminifers and shell fragments present.
20995	440-460 Ctgs	$\bar{R}_v max$ = - Lithology: limestone. Dom rare: I > L, inertinite and liptinite rare, vitrinite absent. Liptinite: rare dinoflagellates and sporinite, yellow. Common foraminifers present. Pyrite abundant.
		Gellibrand Marl
20996	720-740 Ctgs	$\bar{R}_v max$ = - Lithology: limestone. Dom rare: I > L, inertinite and liptinite rare, vitrinite absent. Liptinite: rare dinoflagellates, yellow. Common foraminifers present. Pyrite abundant.
20997	980-1000 Ctgs	$\bar{R}_v max$ = - Lithology: limestone >> siltstone. Dom rare: L > I, liptinite and inertinite rare, vitrinite absent. Liptinite: rare dinoflagellates, yellow; rare sporinite, yellow orange. Common foraminifers present. Pyrite abundant.
20998	1310-1320 Ctgs	$\bar{R}_v max$ = 0.39% Lithology: limestone >> sandstone. Dom rare: I > V > or = L, all macerals rare. Liptinite: rare dinoflagellates, yellow. Common foraminifers and shell fragments present. Framboidal pyrite abundant.
		Unnamed Sands and Silts
20999	1720-1725 Ctgs	$\bar{R}_v max$ = 0.42% Lithology: siltstone > limestone > sandstone. Dom rare: E > I > V, all macerals rare. Liptinite: rare cutinite and sporinite, yellow to yellow orange; rare dinoflagellates, yellow; rare liptodetrinite, yellow to yellow orange. Common foraminifers; framboidal pyrite abundant.

Sample-No.	Depth (m)	Belfast Mudstone
21000	1740-1745 Ctgs	$\bar{R}_v max = 0.45\%$ Lithology: siltstone > carbonate > sandstone; sandstone partly calcareous. Dom common: I > V > L, inertinite sparse to common, vitrinite and liptinite rare. Liptinite: rare sporinite, yellow to orange; rare liptodetrinite, yellow to orange; rare dinoflagellates, yellow. Foraminifers and shell fragments common. Framboidal pyrite abundant.
21001	1920-1930 Ctgs	$\bar{R}_v max = 0.45\%$ Lithology: siltstone >> carbonate > sandstone. Dom common: I > L > V, inertinite common, Liptinite and vitrinite rare. Liptinite: rare sporinite and liptodetrinite, yellow to orange; rare dinoflagellates, yellow to yellow orange. Foraminifers and shell fragments common. Framboidal pyrite abundant.
21002	2115-2125 Ctgs	$\bar{R}_v max = 0.51\%$ Lithology: siltstone >> carbonate > claystone; siltstone partly calcareous. Dom sparse: I > L > V, inertinite sparse, liptinite and vitrinite rare. Liptinite: rare sporinite and liptodetrinite, yellow orange to orange; rare dinoflagellates, greenish yellow to yellow orange; rare ?telalginite, yellow. Shell fragments present. Abundant pyrite, partly framboidal.
21003	2215-2225 Ctgs	$\bar{R}_v max = 0.50\%$ Lithology: siltstone > carbonate > sandstone; siltstone partly calcareous. Dom sparse: I > L > V, inertinite sparse, liptinite and vitrinite rare. Liptinite: rare sporinite and liptodetrinite, yellow orange to orange; rare dinoflagellates, greenish yellow to yellow orange; trace of ?telalginite, yellow. Shell fragments present. Abundant pyrite, partly framboidal.
21004	2360-2370 Ctgs	$\bar{R}_v max = 0.53\%$ Lithology: siltstone > claystone > carbonate. Dom common: I > L > V, inertinite common, liptinite rare, trace of vitrinite.

Sample-No.	Depth (m)	
		Liptinite: rare sporinite and cutinite, yellow orange to dull orange; rare liptodetrinite, yellow orange to dull orange; rare phytoplankton, yellow orange. Abundant pyrite, partly framboidal.
21005	2410-2420 Ctgs	$\bar{R}_v$max = - Lithology: siltstone >> claystone = carbonate. Dom sparse to common: I >> L, inertinite sparse to common, liptinite rare, vitrinite absent. Liptinite: rare phytoplankton, yellow to yellow orange; rare liptodetrinite, yellow orange to dull orange. Common shell fragments. Abundant pyrite, partly framboidal.
21006	2645-2655 Ctgs	$\bar{R}_v$max = 0.53% Lithology: siltstone >> carbonate > claystone. Dom common: I >> L >> V, inertinite common, liptinite rare, trace of vitrinite. Liptinite: rare cutinite and sporinite, orange to dull orange; rare phytoplankton, yellow to yellow orange. Abundant ?texto-ulminite present ($\bar{R}$max = 0.32%). Abundant carbonate grains and shell fragments in siltstone. Framboidal pyrite abundant.
21007	2795-2805 Ctgs	$\bar{R}_v$max = ?0.61% Lithology: siltstone >> carbonate > claystone. Dom common: I > L > V, inertinite common, liptinite rare, vitrinite very rare. Liptinite: rare sporinite and cutinite, orange to dull orange; rare phytoplankton, yellow orange. Common ?texto-ulminite ($\bar{R}$max = 0.42%). Pyrite abundant.
21008	2605-2610 *ST-Ctgs	$\bar{R}_v$max = ?0.64% Lithology: siltstone >> carbonate > claystone > sandstone; siltstone partly calcareous. Dom common, I > L >> V, inertinite common, liptinite sparse, trace of vitrinite. Liptinite: sparse phytoplankton (dinoflagellates), yellow to yellow orange; sparse liptodetrinite, yellow orange to dull orange; rare sporinite, orange to dull orange; rare ?telalginite, yellow. Strong mineral fluorescence. Abundant pyrite, partly framboidal.

* Side-Track

Sample-No.	Depth (m)	
21009	2830 ST-Ctgs	$\bar{R}_v$max = 0.67% Lithology: calcareous siltstone >> carbonate. Dom common, I >> L > V, inertinite common, liptinite and vitrinite rare. Liptinite: rare liptodetrinite, orange to dull orange. Abundant iron oxides present. Abundant pyrite, partly framboidal.
21010	2995-3000 ST-Ctgs	$\bar{R}_v$max = ?0.63 Lithology: siltstone >> claystone > carbonate > sandstone; siltstone partly calcareous. Dom sparse: I >> L > V, inertinite sparse, liptinite rare, trace of vitrinite. Liptinite: rare phytoplankton, yellow to yellow orange; rare liptodetrinite, orange to dull orange. Abundant pyrite, partly framboidal.
21011	3205-3210 ST-Ctgs	$\bar{R}_v$max = - Lithology: siltstone >> claystone > carbonate; siltstone partly calcareous. Dom sparse: I >> L, inertinite sparse, liptinite rare, vitrinite absent. Liptinite: rare phytoplankton, yellow to yellow orange, rare liptodetrinite, yellow orange to dull orange. Abundant iron oxides present. Abundant pyrite.
21012	3250 ST-Ctgs	$\bar{R}_v$max = 0.86% Lithology: siltstone > carbonate > claystone; siltstone partly calcareous. Dom sparse: I > L > V, inertinite sparse, liptinite and vitrinite rare. Liptinite: rare liptodetrinite, orange to dull orange. Moderate mineral fluorescence. Abundant iron oxides present. Abundant pyrite.
21013	3370 ST-Ctgs	$\bar{R}_v$max = 0.93% Lithology: calcareous siltstone > claystone = carbonate. Dom common: I >> L > V, inertinite common, liptinite and vitrinite rare. Liptinite: rare liptodetrinite, dull orange. Abundant iron oxides present. Abundant pyrite.

Sample-No.	Depth (m)	

Waarre Formation

Sample-No.	Depth (m)	Description
21014	3420 ST-Ctgs	$\bar{R}_v max = 0.93\%$ Lithology: sandstone >> carbonate > siltstone; siltstone partly calcareous. Dom sparse: I >> V > L, inertinite sparse, vitrinite rare, trace of liptinite. Liptinite: trace of liptodetrinite, dull orange. Iron oxides present. Pyrite abundant.
21015	3425 ST-Ctgs	$\bar{R}_v max = 0.99\%$ Lithology: sandstone > calcareous siltstone > carbonate. Dom common: I >> V >> L, inertinite common, vitrinite rare, trace of liptinite. Liptinite: trace of liptodetrinite, dull orange. Iron oxides present. Pyrite abundant.
21016	3500-3510 ST-Ctgs	$\bar{R}_v max = 1.00\%$ Lithology: sandstone >calcareous siltstone > carbonate. Dom common: I >> V, inertinite common, vitrinite rare, liptinite absent. Iron oxides present. Pyrite abundant.

Sample No.	Project	Depth	Date	Operator

Reflectance readings

Rmax %	Range	No.

Fluorescence	G	Y	O	DO	B
Cutinite					
Sporinite					
Resinite					
Telalg.					
D / Achr.					
Lipd.					
Suber.					
Exs.					
Fluor.					
Bit.					

	V %	I %	E %	DOM %
Major				
Abundant				
Common				
Sparse				
Rare				

> > DOM

Coal

% ______

V ______

I ______

E ______

ML ______

Shaly Coal

% ______

V ______

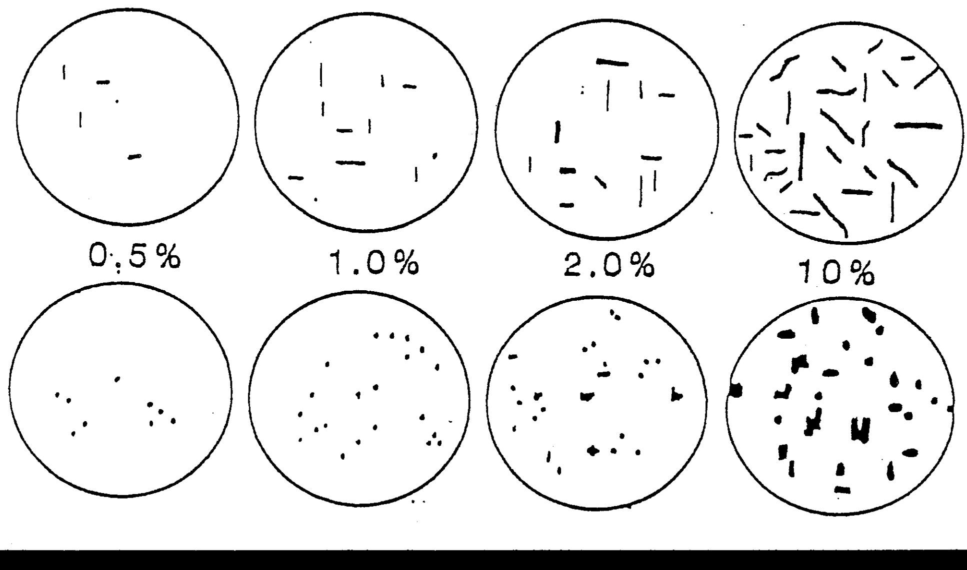
I ______

E ______

MM ______

ML ______

Remarks :



	Sandstone				Siltstone				Claystone				Carbonate				Others				Coal			Shaly Coal		
	V	I	E	D	V	I	E	D	V	I	E	D	V	I	E	D	V	I	E	D	V	I	E	V	I	E
5																										
10																										
15																										
20																										
25																										
30																										
35																										
40																										
45																										
50																										

_____ % _____ % _____ % _____ % _____ % _____ % _____ %

Major + > 10%

Abundant x 2 - 10%

Common | 0.5 - 2%

Sparse = 0.1 - 0.5%

Rare - < 0.1%

Absent 0 zero

KARWEIL DIAGRAM (AFTER BOSTICK)