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PEP111

OTWAY BASIN

Organic petrology of samples from a set of twenty one wells from the Otway Basin

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A report prepared for
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September 1980

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CONTENTS (continued)

The organic petrology of samples from a suite of twenty one samples from the Otway Basin

Ninety four samples from twenty one wells from the Otway Basin (Figure 1) were examined as polished sections in reflected light. An attempt to measure vitrinite reflectance was made for all samples. Some do not appear to contain vitrinite, but acceptable measurements were made for a majority of the samples. Maceral abundance was estimated in reflected white light and in violet/UV reflected light fluorescence mode. Exinite abundance data are based almost entirely on the fluorescence mode observations. The majority of the samples were from conventional core but a number of cuttings samples were also examined. The number of samples available per well ranged from one to seven. For some wells, the combination of sample quality (absence of vitrinite and, in the case of cuttings samples, contamination by cavings) and the small number of samples made it impossible to construct an accurate vitrinite reflectance depth profile. In all cases, however, by combining reflectance data with observations on exinite fluorescence colour, it was possible to estimate the level of maturity in general terms (immature, mature, overmature). The information concerning source-potential (organic matter abundance and type) can only be regarded as preliminary in view of the small number of samples per well and the possibility of bias towards specific rock types in the choice of horizon at which the cores were cut.

The cuttings samples were prepared as grain mounts. Core samples were sawn and mounted so that the section polished is perpendicular to bedding. In a few cases, the friability of the core was such that the rock was broken to approximately -4mm to obtain better impregnation with the mounting resin.

The observations provide information on both maturity and source-potential. Comparison with present well temperatures and with available data for other wells allows inferences to be made concerning some aspects of the thermal history of the Otway Basin. The coverage afforded by the data from the twenty one wells also allows some generalizations to be made concerning the vertical and lateral patterns of rank variation (maturity) within the Otway Basin sequence.

Maturation data

The vitrinite reflectance measurements were made using a Leitz MPV 1 photometer; a fluorite lens (n.a. 0.85); plane polarized light; refractive index of the immersion oil 1.518 @ 23°C, wavelength 546nm; and standards spinel 0.42%, Yag 0.92% and GGG 1.76%. The conditions for the fluorescence observations were BG3 excitation filter, TK400 dichroic mirror and a K490 barrier filter. Both the fluorescence mode and the reflected light mode photographs were taken with the dichroic mirror as the illuminator to ensure accurate registration of fields in the two modes. A K460 filter (pale green cast) was used for the reflected light to avoid the complex colour cast given by the dichroic mirror.

The reflectance data for each well together with notes on exinite fluorescence colours and some aspects of the petrology are given in a set of Appendices listed in alphabetical order by well name. A brief description of the organic petrology of the samples including a summary of maturation characteristics for each well is given in a facing page to each set of vitrinite reflectance data. A set of figures plotting vitrinite reflectance against depth and including some present well-temperature data are set out in Figures 1 to 21 (pages 17 to 38) and are also set out in alphabetical order by well name. The Plates are set out by wells in alphabetical order, and in depth order, for each well, on pages 74 to 104.

Table 1 gives a summary of the indications from the reflectance and fluorescence data concerning the maturity zones penetrated in the wells. Seven wells failed to penetrate beyond the zone of initial maturity (0.5% to 0.7% $\bar{R}_o$max) and only four reached the base of the zone of prolific oil generation (0.7% to 0.9% $\bar{R}_o$max). One well was drilled to the oil deadline at 1.3% $\bar{R}_o$max and for this well (Fergusons Hill No. 1) the petrographic evidence suggests that localized thermal metamorphic effects have disturbed the regional coalification pattern. Local contact metamorphism may, additionally, have affected the section found in Kalangadoo No. 1.

Table 1. Summary of the maturity zones penentrated by the wells sampled

Well name	Depth to top of maturity zone penetrated Initially mature 1	Mature 2	Late mature 3	Overmature 4	Evidence of local thermal alteration
ARGONAUT No.1	2400	3300			
BELFAST No.4	(1800)				
BURRUNGULE No.1	1400	(2600)			
CAROLINE No.1	2000	2900	3300		
CASTERTON No.2	Probably immature at T.D. of 1526m				
FERGUSONS HILL No.1	1000	2500	?3000	?3300	Unusually high reflectance near T.D.
FLAXMANS No.1	1900	2800	3200		
GLENELG No.1	?1600	?2200			
HEYWOOD No.10	1600				
KALANGADOO No.1	1800	2000			High reflectance gradient near T.D.
LAKE BONNEY No.1	2000				
MOUNT SALT No.1	2300	3000			
MUSSEL No.1	1900				
NAUTILUS No.1	1900				
NORTH EUMERALLA No.1	1700	2600			

1 - 0.5% $\bar{R}_o$max 2 - 0.7% $\bar{R}_o$max 3 - 0.9% $\bar{R}_o$max 4 - 1.3% $\bar{R}_o$max

Depths are in brackets where extrapolation was used

Table 1. Summary of the maturity zones penetrated by the wells sampled (continued)

Well name		Depth to top of maturity zone penetrated				Evidence of local thermal alteration
		Initially mature	Mature	Late mature	Overmature	
		1	2	3	4	
PECTEN No.1 and No.1A		1800	2400			
PORT CAMBELL No.2		1900	2200			
PORTLAND No.1			?1500			
PRETTY HILL No.1		1300	1700			
ROWANS No.1		1300				
VOLUTA No.1		2300	2900	3500		
Average		1763	2471	3250	3300	
Number of wells		19	14	4	1	
Range	Shallowest	1000	1500	3000		
	Deepest	2400	3300	3500		

1 - 0.5% $\bar{R}_o$max   2 - 0.7% $\bar{R}_o$max   3 - 0.9% $\bar{R}_o$max   4 - 1.3% $\bar{R}_o$max

Depths are in brackets where extrapolation was used

Figures 22 and 23 show, respectively, the contours of the depths to the 0.5% and 0.7% vitrinite reflectance horizons. The contours follow the general tendency for the section to thicken offshore. Similar information is given in section form in Figure 26 for the set of wells lying on the line AB shown in Figure 25. From Figures 25 and 26 it is clear that while reflectance gradients can be higher in the onshore basin, the reduced thickness of section in parts of the Otway Basin mean that the full, oil mature section is probably not present in a significant part of the onshore basin. Figures 22 and 23 indicate that significant inflexions of the contour lines are associated with structural features such as the Gambier and Portland Embayments.

Reflectance gradients are shown in Table 2 and those at the 0.6% vitrinite reflectance level are plotted on Figure 24. The variation in reflectance gradient appears to be too irregular to warrant the drawing of contour lines. Most of the high reflectance gradients are associated with a known shallow depth to basement or the presence of igneous rocks near the base of the sequence drilled. In the case of Kalangadoo, basement was not reached in the well but can be presumed to be relatively shallow. Temperatures at the 0.5, 0.7, 0.9, and 1.3% $\bar{R}_o$max horizon are listed in Table 3 and will be discussed in the section on Thermal History.

Depths to the main oil generation zone are generally of the order of 2000 metres or less onshore and well in excess of 2000 metres offshore. Although the full, oil

Table 2. Reflectance gradients at the 0.6% and 0.9% vitrinite reflectance levels.

Reflectance gradient at	$0.6\%\bar{R}_o$max %/km	$0.9\%\bar{R}_o$max %/km
Argonaut No.1	0.23	
Belfast No.4	-	
Burrungule No.1	-	
Caroline No.1	0.20	0.70
Casterton No.2	-	
Fergusons Hill No.1	0.10	0.90
Flaxmans No.1	0.24	0.68
Glenelg No.1	?low	
Heywood No.10	-	
Kalangadoo No.1	0.96	
Lake Bonney No.1	low	
Mount Salt No.1	0.27	
Mussel No.1	?0.28	
Nautilus No.1	-	
North Eumeralla No.1	0.25	
Pecten No.1 and No.1A	0.35	
Port Campbell No.2	0.45	
Portland No.1	-	
Pretty Hill No.1	0.60	
Rowans No.1	-	
Voluta No.1	0.32	0.30

mature section is probably not present in relatively large areas of the onshore basin, complete sections occur in a number of embayments. A complete, oil mature section has not been penetrated in any of the offshore wells studied but the oil mature section clearly is both thicker and more complete in the offshore parts of the basin.

Organic matter type

Short notes on the organic matter type and the relative abundance of the maceral groups are given in the sample results section by well, listed in alphabetical order. The short well-description summarizes some aspects of the organic matter for the suite of samples from each well. Figures 27 to 34 have been compiled to aid in summarizing the full set of data on organic matter type. Plates 1 to 32 illustrate some of the features of the organic matter.

Dispersed organic matter (d.o.m.) is abundant in most samples and sparse or rare in very few samples. The majority of the d.o.m. in most samples is inertinite which is considered by most authors to have relatively poor hydrocarbon generating capacity. Exinite and vitrinite are common or abundant in relatively few samples. Coal (Plates 3 to 6, 14, 15, 21, 22, 26, 27 and 30) is the only lithology which has a consistently high percentage of exinite (and vitrinite).

The Tertiary sediments have a lower abundance of d.o.m. than the Cretaceous samples. The Tertiary is generally immature or at best maginally mature, but it has been suggested that calcareous source-rocks (Plates 16 and 17)may mature earlier than epi-clastic source-rocks. In this context the presence of pervasive fluorescence from most of the carbonate sediments, and the fluorescence of some of the nannofossils (Plate 17), may indicate that observations on discrete d.o.m. could underestimate the source-potential of the Tertiary part of the sequence.

Some differences are evident in the nature of the d.o.m. in the major subdivisions of the Cretaceous succession in Figures 27, 28, 29 and 31 to 34. However, the basic pattern of the dominance of inertinite in the d.o.m., and the tendency for the mode for both exinite and vitrinite to be in the sparse or rare categories, is consistent. Dinoflagellates and alginite (Plate 16) were observed in a significant number of samples, and shell fragments are common in many samples. The majority of the exinite is, nevertheless, of higher plant origin (Plates 9, 12, 13, 18, 19, 20, 21, 28) – as, of course, are the vitrinite and the inertinite.

Exsudatinite and bitumens are present in a number of samples but are not prominent components. Exsudatinite occurs in a number of coals and is of interest since its presence suggests that hydrocarbon mobilization, and at least some migration, has occurred within the coals.

Detrital coals are common in a number of samples suites (e.g. Flaxmans). The coals clasts are unusual in that they appear to have been eroded after developing sub-bituminous or bituminous textures, but have the same or similar reflectance to what appears to be first generation vitrinite occurring in the same sample. No explanation can be given for this unusual form of occurrence.

The d.o.m. in the majority of samples is probably reworked (Plates 1, 13 and 32). In some cases this has produced both physical and chemical alteration. Oxidized humic matter is the main component, as noted above, and in many cases massive low reflectance inertinite (Plate 1 and 8) makes difficult the distinction of vitrinite from inertinite. Equally, some samples have significant amounts of vitrinite derived from bark or similar tissue and this has a relatively low reflectance. These two effects combine to produce, for some samples, an unusually wide range of reflectance. Checks with adjacent coals or obviously autochthonous vitrinite (Plate 10 and 11), show that the means of the reflectance of the vitrinite populations are stable and neither of these type effects appears to have significantly influenced the assessment of source-rock maturity.

Strong positive alteration was noted in the fluorescence characteristics of some of the cutinite and sporinite, and for the background fluorescence in some of the shaly coals (Plate 26).. Weak negative alteration was noted for some of the fluorinite.

Pyrite rather than siderite is widely distributed in most of the Cretaceous units, indicating marine, or other saline influence for a significant part of the Cretaceous succession.

Exsudatinite (Plates 21 and 22) and possible bitumens (Plate 25) are present. Some "fluorinites" (Plate 24) may be dead oil (Plate 29).

Mineral fluorescence occurs in some vein carbonates (Plate 7) and rim fluorescence is present on some sand-sized quartz grains (Plate 31).

Thermal History

It has been noted above that rank variation is related in a general way to basement at both the overall basin level of variation and in relation to the smaller sub-basins or embayments. From Figure 26 it is clear that the depth to any given reflectance horizon is, in general, inversely related to the thickness of the Upper Cretaceous succession. The presence of volcanics near the base of the sequence also appears to have an influence on maturity, but it is not clear whether this is a function of magmatic heating (less likely) or of greater conductivity and heat generation (more likely). The evidence from Figure 26 does not, on balance, support the existence of significant folding and uplift after the major episode of coalification.

In an attempt to assess further the thermal history of the sequence in the Otway Basin, average temperatures have been calculated for a number of reflectance horizons (Table 3). The temperatures have been derived from logging-run data corrected by using the 10% rule. The temperatures in Table 3 are similar to equivalent data for the Perth Basin sequences (greater average age) but are much less than those for either the Bass or Gippsland Basin (lower average age). They are also much less than the averages for the Cooper Basin and for the Carnarvon Basin, both of which have average ages at each reflectance horizon much greater than the ages for the Otway Basin sequences.

Table 3. Present well-temperatures in °C at the 0.5%, 0.7%, 0.9% and 1.3% vitrinite reflectance horizons.

		0.5% $\bar{R}_o$	0.7% $\bar{R}_o$	0.9% $\bar{R}_o$	1.3% $\bar{R}_o$
Mean temperature		67.6	89.3	104	124
Number of wells		16	11	4	1
Range	Low	50	72	100	-
	High	77	110	108	-

Table 4 compares present well temperatures with temperatures derived from the vitrinite reflectances and two models of coalification. The isothermal model assumes the temperature has applied over the entire sediment age, whereas the gradthermal model assumes a history of constantly rising temperature throughout the history of the sediment with the present temperature being the maximum

Table 4. Depth, reflectance and model temperature data for well which reached a vitrinite reflectance of 0.7% or greater.

Depth m	Vitrinite Reflectance % $\bar{R}_o$max	Present Well Temperature °C	Calculated Temperature Isothermal °C	Calculated Temperature Gradthermal °C	$T_{Pres} - T_{Grad}$
ARGONAUT					
3300	0.7	90	70	112	(-22)
CAROLINE					
2900	0.7	97	65	104	(- 7)
3300	0.9	102	85	136	(-34)
FERGUSONS HILL					
2500	0.7	91	65	104	(-13)
?3000	0.9	100	85	136	(-36)
?3300	1.3	124	95	152	(-28)
FLAXMANS					
2800	0.7	92	65	104	(-12)
3200	0.9	108	85	136	(-24)
KALANGADOO					
2000	0.7	81	65	104	(-23)
MOUNT SALT					
3000	0.7	88	70	112	(-24)
NORTH EUMERALLA					
2600	0.7	110	65	104	(+6)
PECTEN					
2400	0.7	88	65	104	(-16)
PORT CAMPBELL					
2200	0.7	80	70	112	(-32)
PRETTY HILL					
1700	0.7	72	65	104	(-32)
VOLUTA					
2900	0.7	94	70	112	(-18)
3500	0.9	107	90	144	(-37)

reached. Neither of these models is likely to be the actual history, but each provides a basis for comparison with the present well-temperature. By using comparisons within a data set for samples of similar reflectance and age, systematic errors which may be present in the model should be largely self-cancelling. Further details, of this use of coalification models, are given in Cook (1979).

The data in Table 4 show that the Gradthermal model temperature is greater than the present well temperature for all wells except North Eumeralla where it is slightly less. The full range is from 6°C less to 37°C greater (Voluta at 0.9% reflectance) than the present well temperatures. This contrasts markedly with a number of other Australian sedimentary basins where the gradthermal temperatures are significantly below the present well temperatures. The Otway Basin data imply an early relatively rapid phase of coalification. No breaks in the reflectance profiles are evident at any of the reflectance profiles so that these breaks in sedimentation do not appear to be associated with any major phase of cover removal. The control on vitrinite reflectance is relatively poor for the Tertiary, but again, the reflectance profiles appear to be continuous with those in the Cretaceous. Thus, although early rapid coalification is indicated for the Otway Basin Cretaceous sequence, significant post-Cretaceous coalification has also occurred.

Figure 26 indicates that the Lower Cretaceous section is much more strongly coalified as compared with the Upper Cretaceous. The data in Table 4 indicate similar differences in model and present well-temperatures for the Upper and Lower Cretaceous section at a number of locations. This must be interpreted as indicating that the younger more recently buried sections offshore, had a very similar coalification history as compared with the older, thinner onshore sequences. There does not appear to be a trend for a difference in the relative timing of coalification from onshore to offshore in the Otway Basin.

Temperatures within the Cretaceous parts of the section probably reached temperatures similar to, or in some cases in excess of, present temperatures by the end of the Cretaceous or during the Early Tertiary. For Voluta and a number of other wells, the Isothermal model temperatures approach the present well-temperatures. The thermal regime since the Early Tertiary has been of falling temperatures, or at best steady formation temperatures with a falling geothermal gradient. The basin is, therefore, relatively "dead" in thermal terms and whilst the thermal drive on maturation and migration would have been high early in the history of the basin, this drive has now decreased markedly.

North Eumeralla may mark a significant departure from the basin-wide trend and, typically, variation within basins is relatively high so that some areas within the Otway Basin may be more active in their more recent maturation history than the basin average.

Conclusions

The majority of samples contain abundant dispersed organic matter (d.o.m.) but this is dominated by inertinite and exinite is relatively rare. Extensive reworking of organic matter is common. Exinite is abundant only in coal-related lithologies. Exsudatinite and some poorly-defined bitumens attest to at least limited migration of petroleum-type products within the section.

Most wells penetrated beyond the initially mature zone but few reached the oil deadline. Vitrinite reflectance shows strong structural control and isoreflectance surfaces rise markedly from offshore to onshore, especially where the Upper Cretaceous sequence is thin. The evidence suggests relatively rapid, early coalification over most of the basin and a post-Early Tertiary history of constant or possibly falling temperatures with a lowered thermal drive on maturation and migration. Localized exceptions to this pattern may occur.

References

Cook, A.C. 1979. Organic petrology of a suite of samples from Jupiter No. 1. A report prepared for Phillips Australia Oil Company. October 1979, 36P.

Figures 1 to 21:- depth - reflectance profiles for the twenty one wells sampled in this study. In some cases, such as North Eumeralla No. 1, the best estimate line has been drawn having regard to open-file data for other nearby wells (Eumeralla No. 1 for North Eumeralla No. 1). The best estimate line is, in general, weighted towards the mean reflectance values but is qualified by the observations made on vitrinite type during the measurement of the reflectances. The range, in conjunction with the data for the number of fields measured, is a measure of the precision of the reflectance data.

FIG. 1

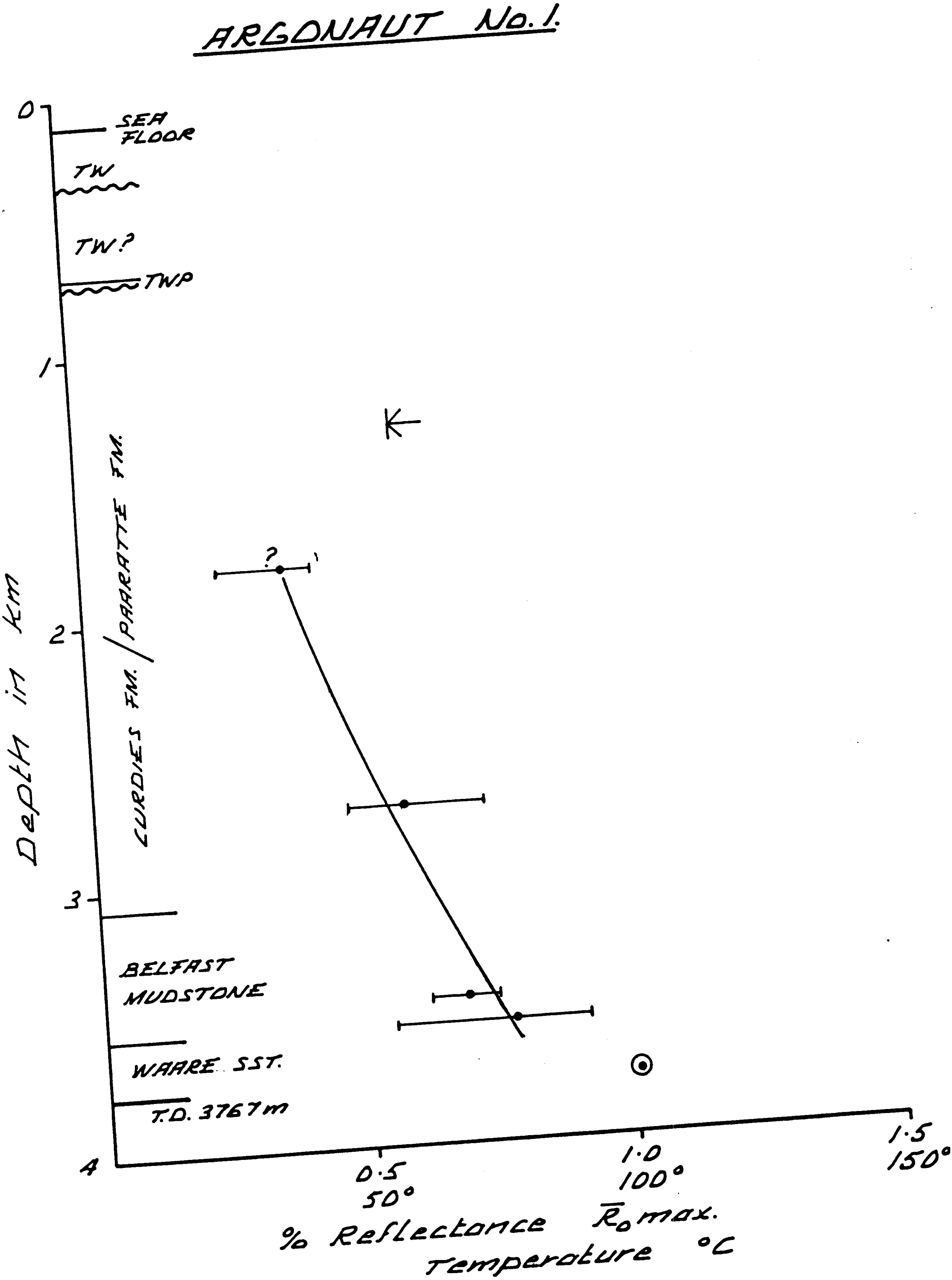
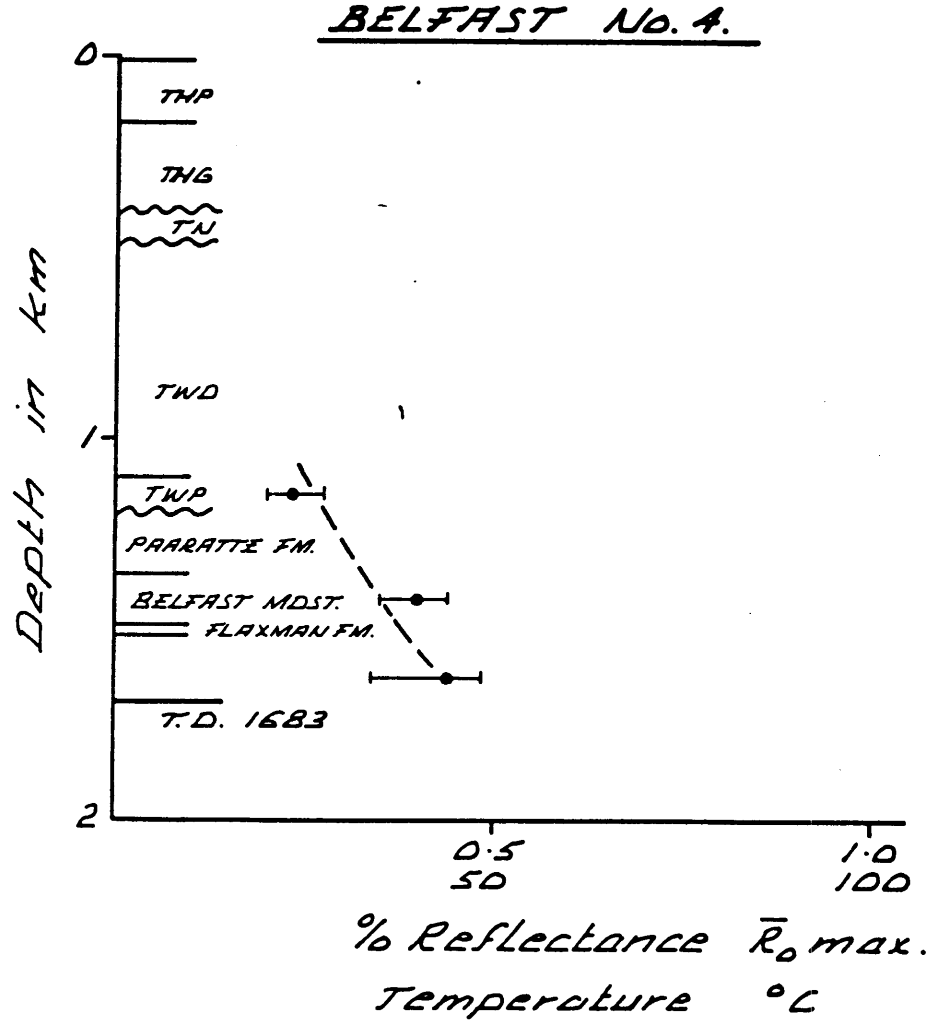

ARGONAUT No. 1.
0
1
2
3
4
SEA FLOOR
TW
TW?
TWP
CURDIES FM. / PARRATTE FM.
BELFAST MUDSTONE
WAARE SST.
T.D. 3767m
Depth in km
?
0·5
50°
1·0
100°
1·5
150°
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 2



BELFAST No. 4.

FIG. 3

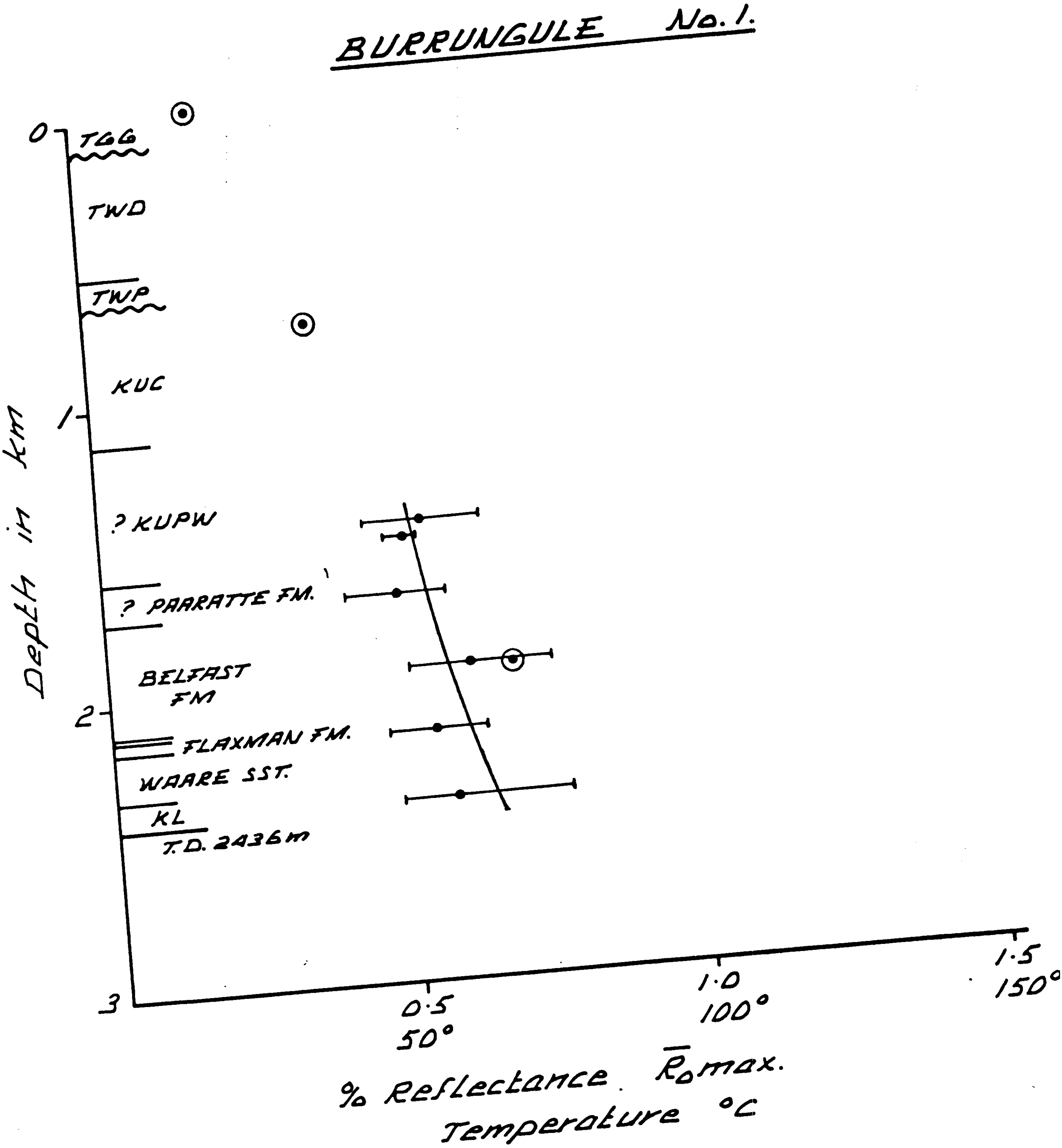
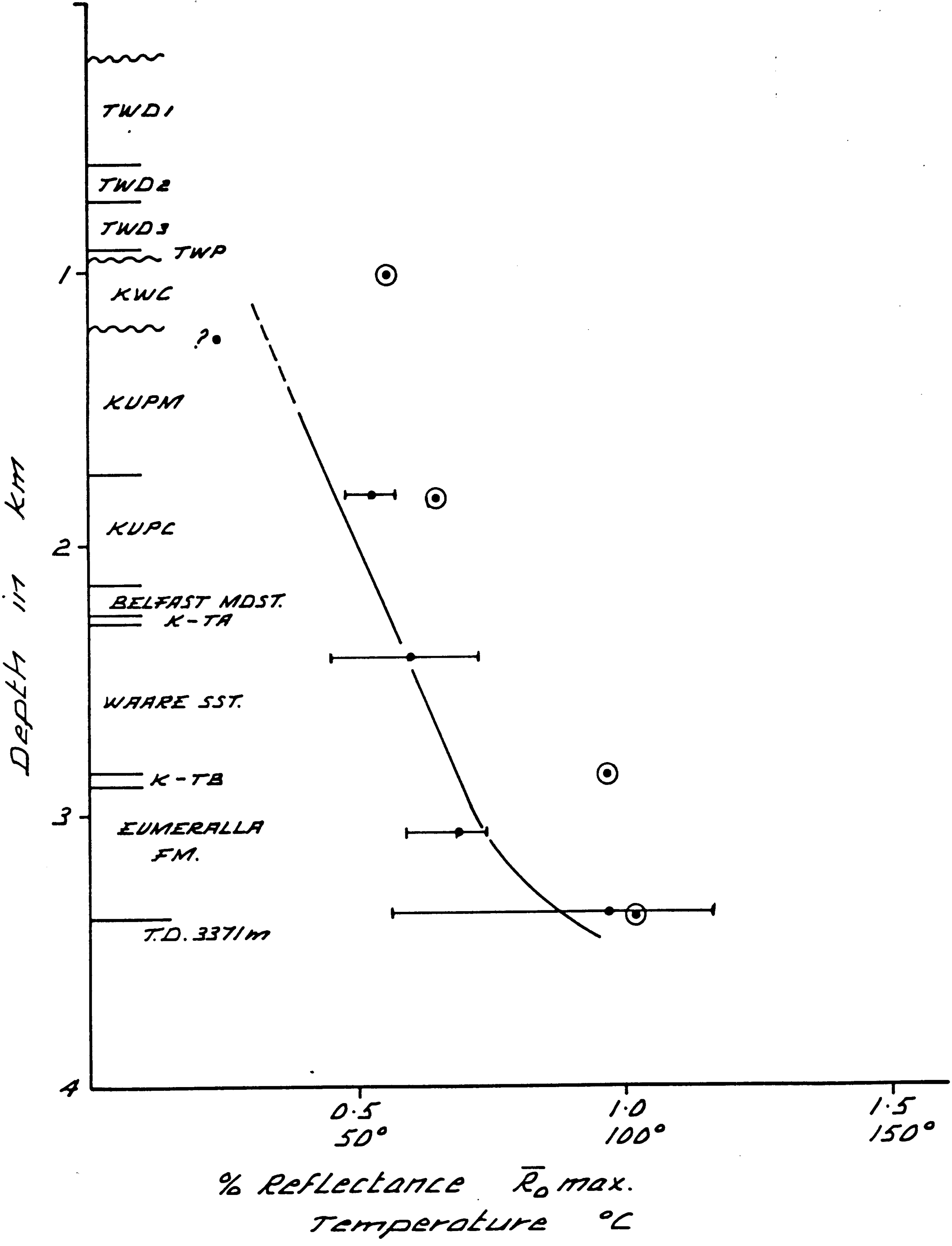

BURRUNGULE No. 1.
0
TGG
TWD
TWP
KUC
1
? KUPW
? PAARATTE FM.
BELFAST FM
2
FLAXMAN FM.
WAARE SST.
KL
T.D. 2436m
3
Depth in km
0·5
50°
1·0
100°
1·5
150°
% Reflectance R̄o max.
Temperature °C

FIG. 4



CAROLINE No. 1.

OIL and GAS DIVISION

FIG. 5

CASTERTON No. 2.

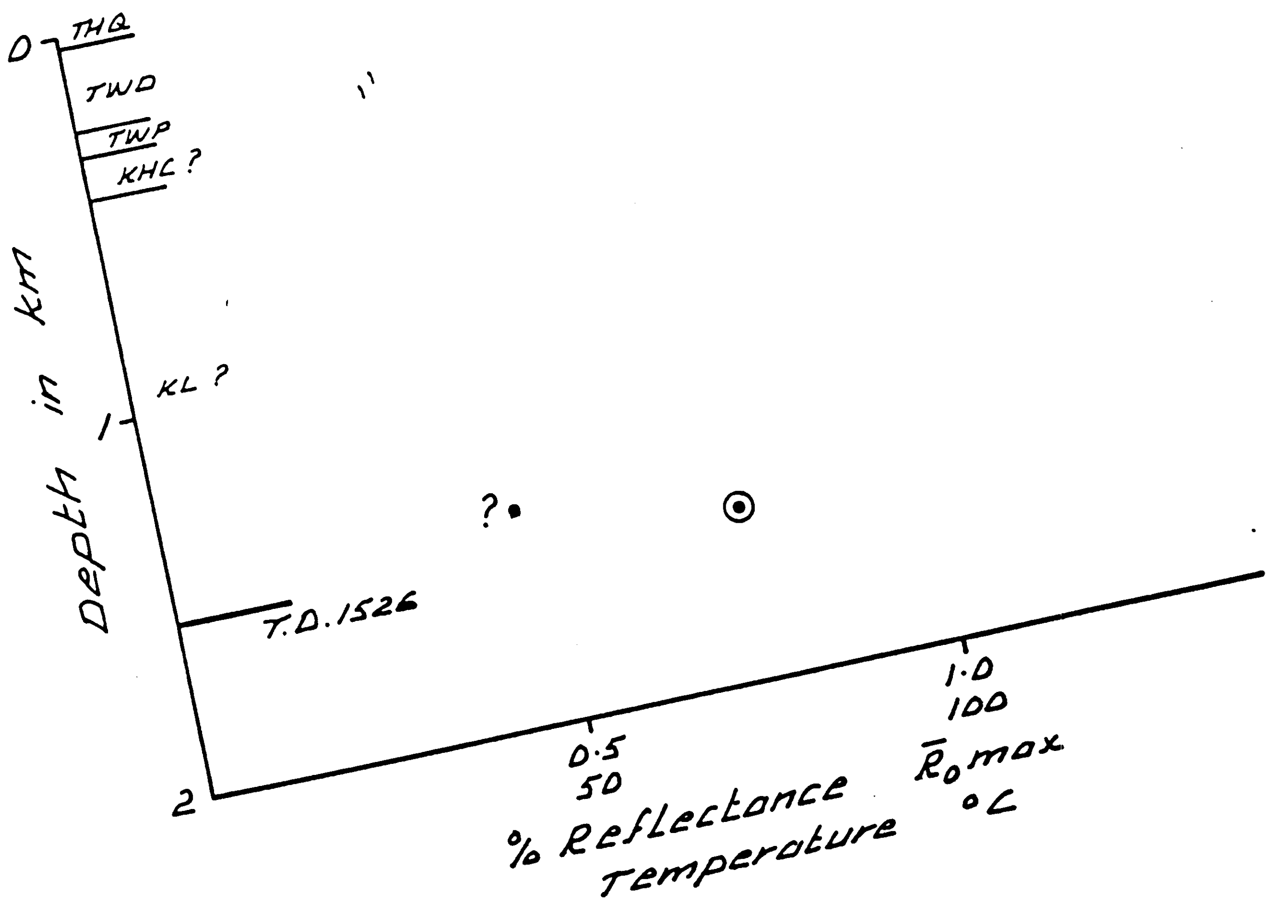


FIG. 6

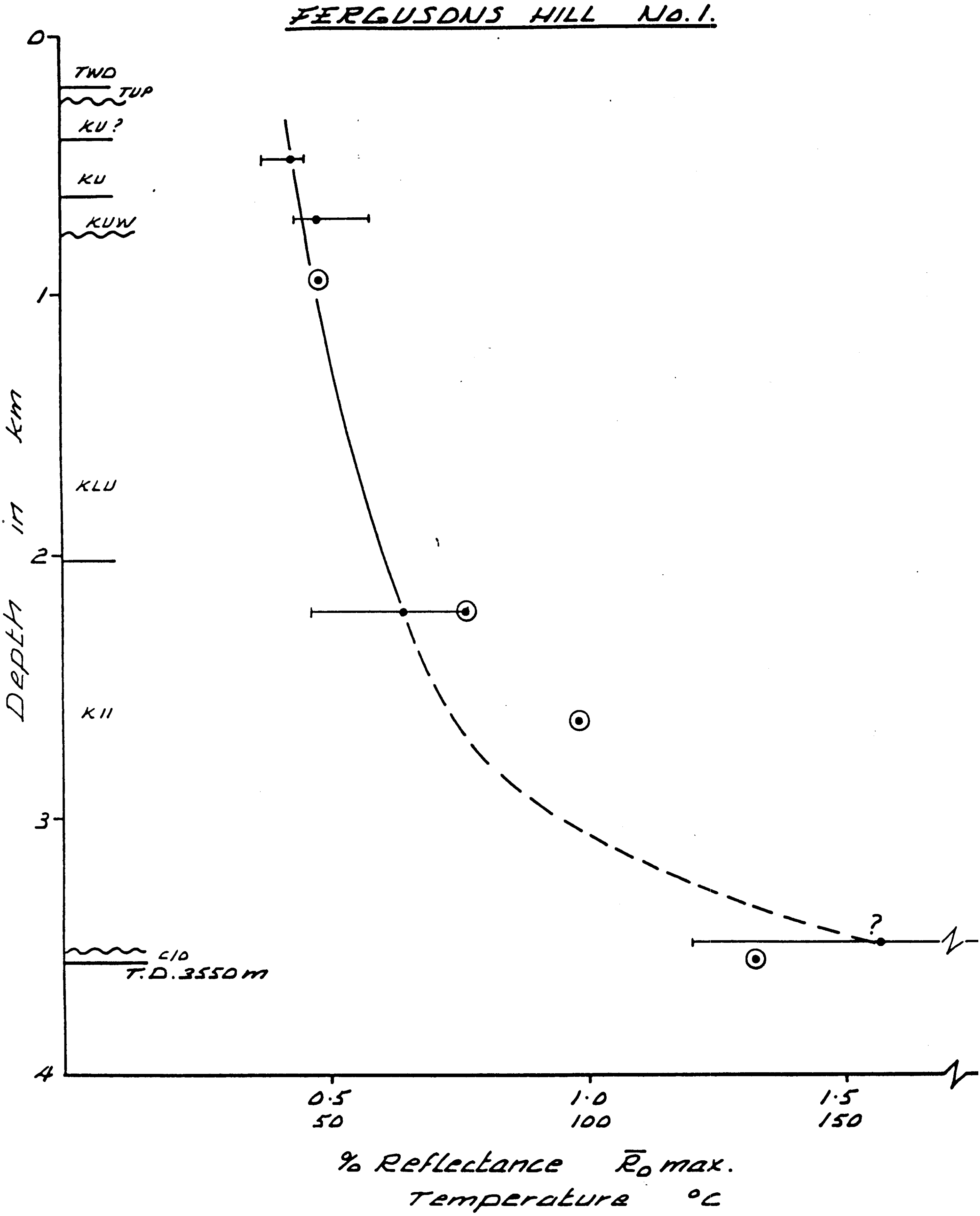

FERGUSONS HILL No.1.
0
1
2
3
4
Depth in km
TWD
TUP
KU?
KU
KUW
KLU
K11
C10
T.D.3550m
?
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_0$ max.
Temperature °C

FIG. 6

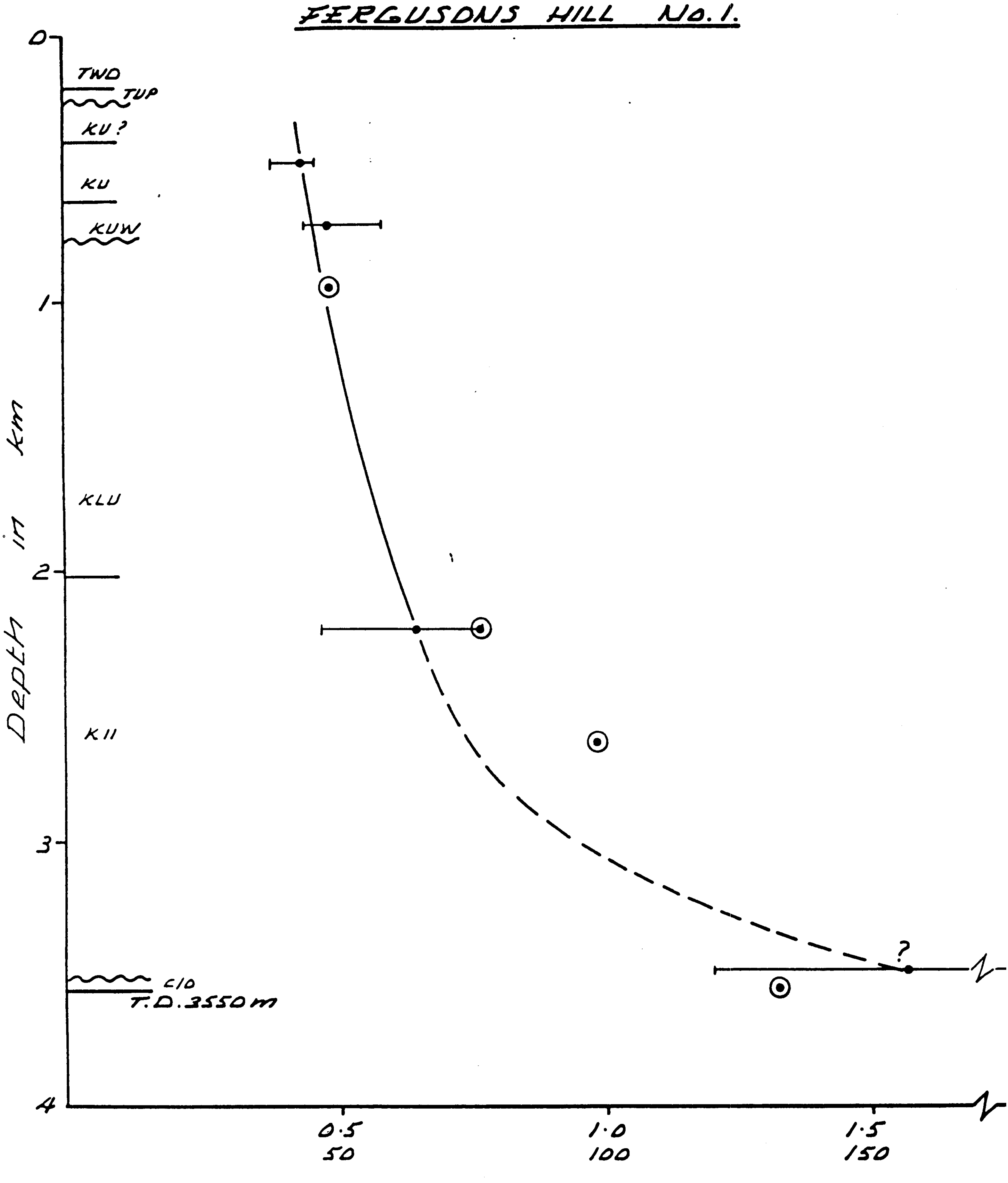

FERGUSONS HILL No.1.
0
1
2
3
4
Depth in km
TWD
TUP
KU?
KU
KUW
KLU
KII
C/O
T.D.3550m
?
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 7

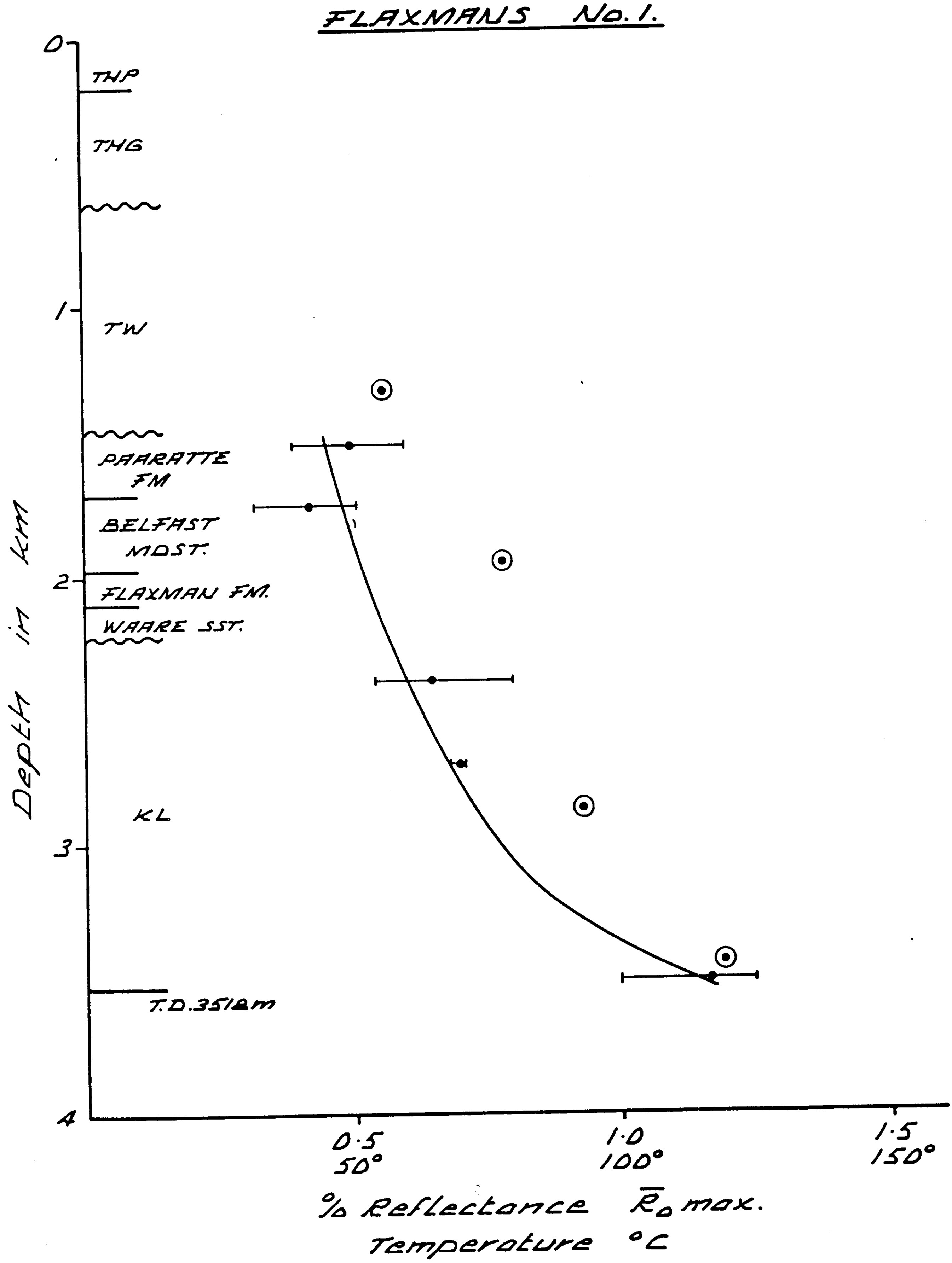

FLAXMANS No. 1.
0
1
2
3
4
THP
THG
TW
PAARATTE FM
BELFAST MDST.
FLAXMAN FM.
WAARE SST.
KL
T.D. 3518m
Depth in km
0·5
50°
1·0
100°
1·5
150°
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 8

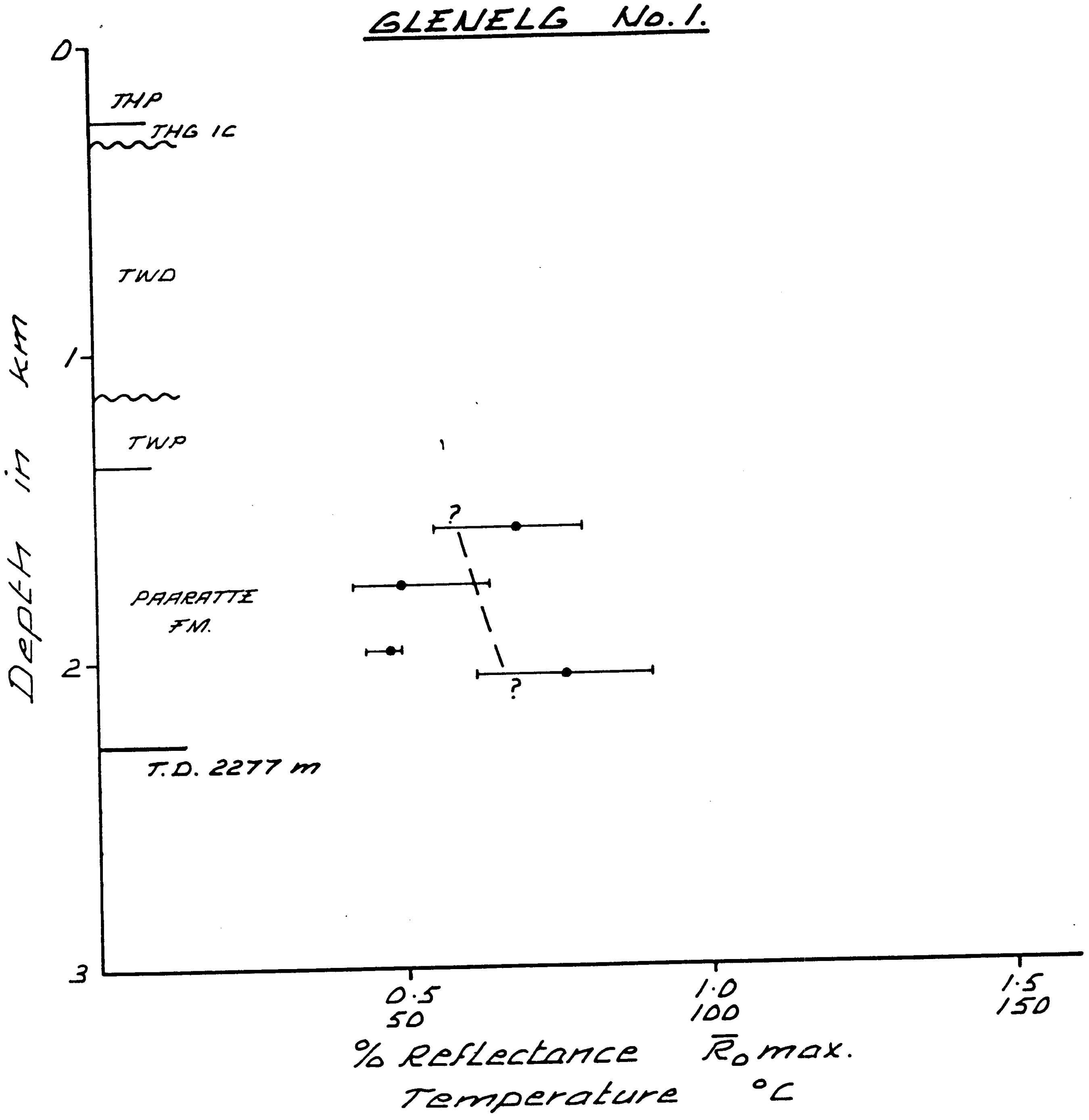

GLENELG No. 1.
0
1
2
3
Depth in km
THP
THG IC
TWD
TWP
PAARATTE FM.
T.D. 2277 m
?
?
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 9

HEYWOOD No.10.

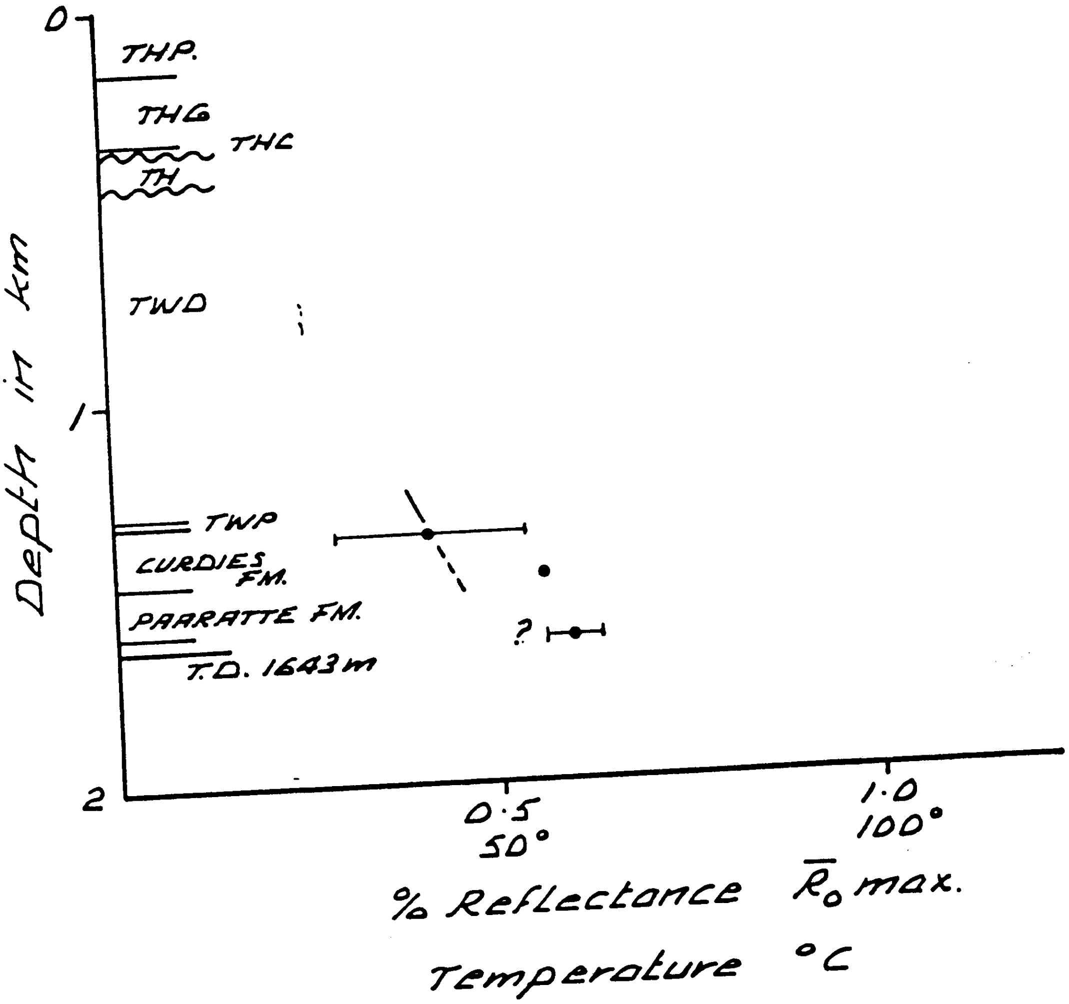


FIG. 10

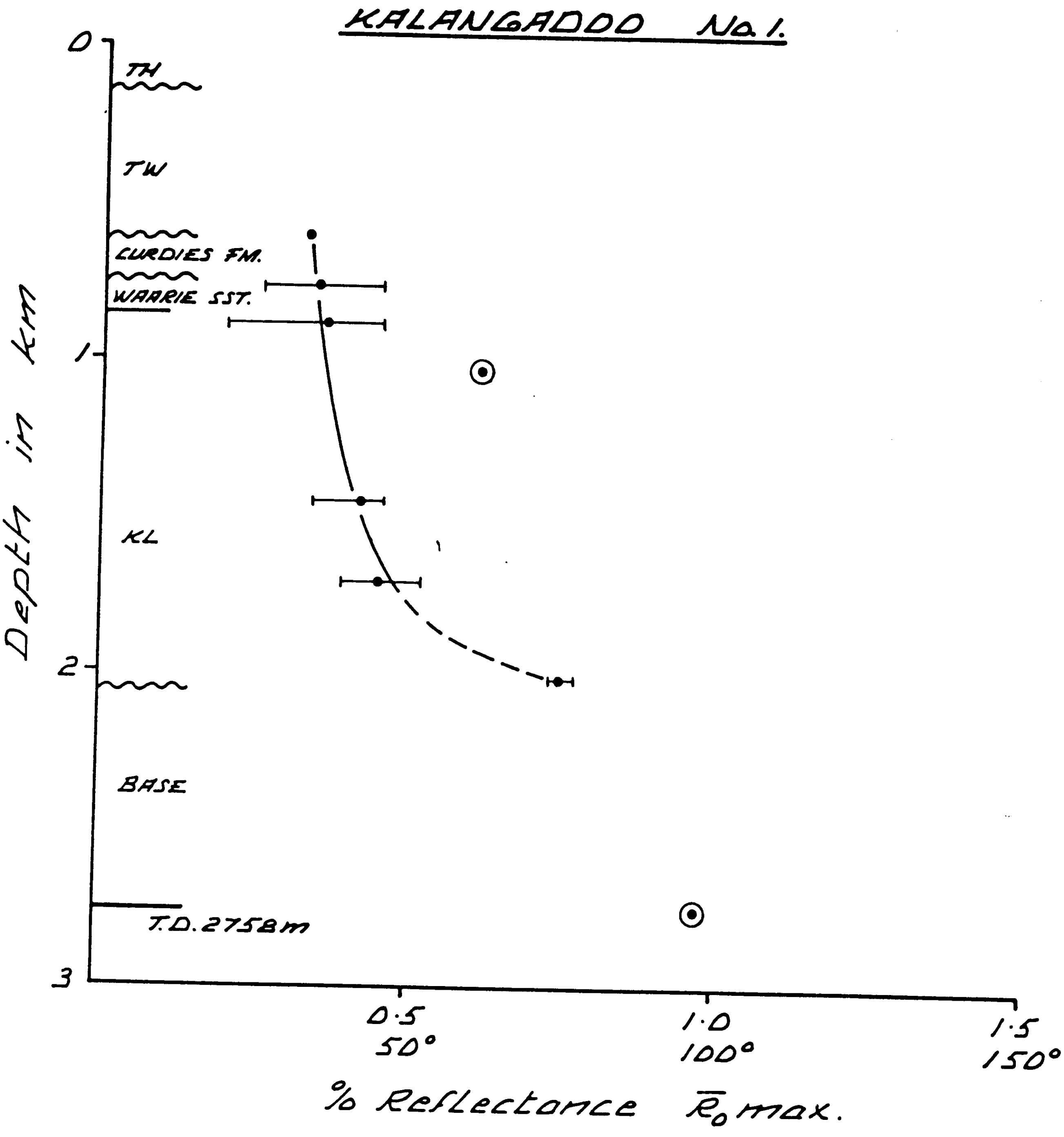

KALANGADDO No. 1.
0
1
2
3
Depth in km
TH
TW
CURDIES FM.
WAARIE SST.
KL
BASE
T.D. 2758m
0·5
50°
1·0
100°
1·5
150°
% Reflectance $\bar{R}_0$ max.
Temperature °C

FIG. 11

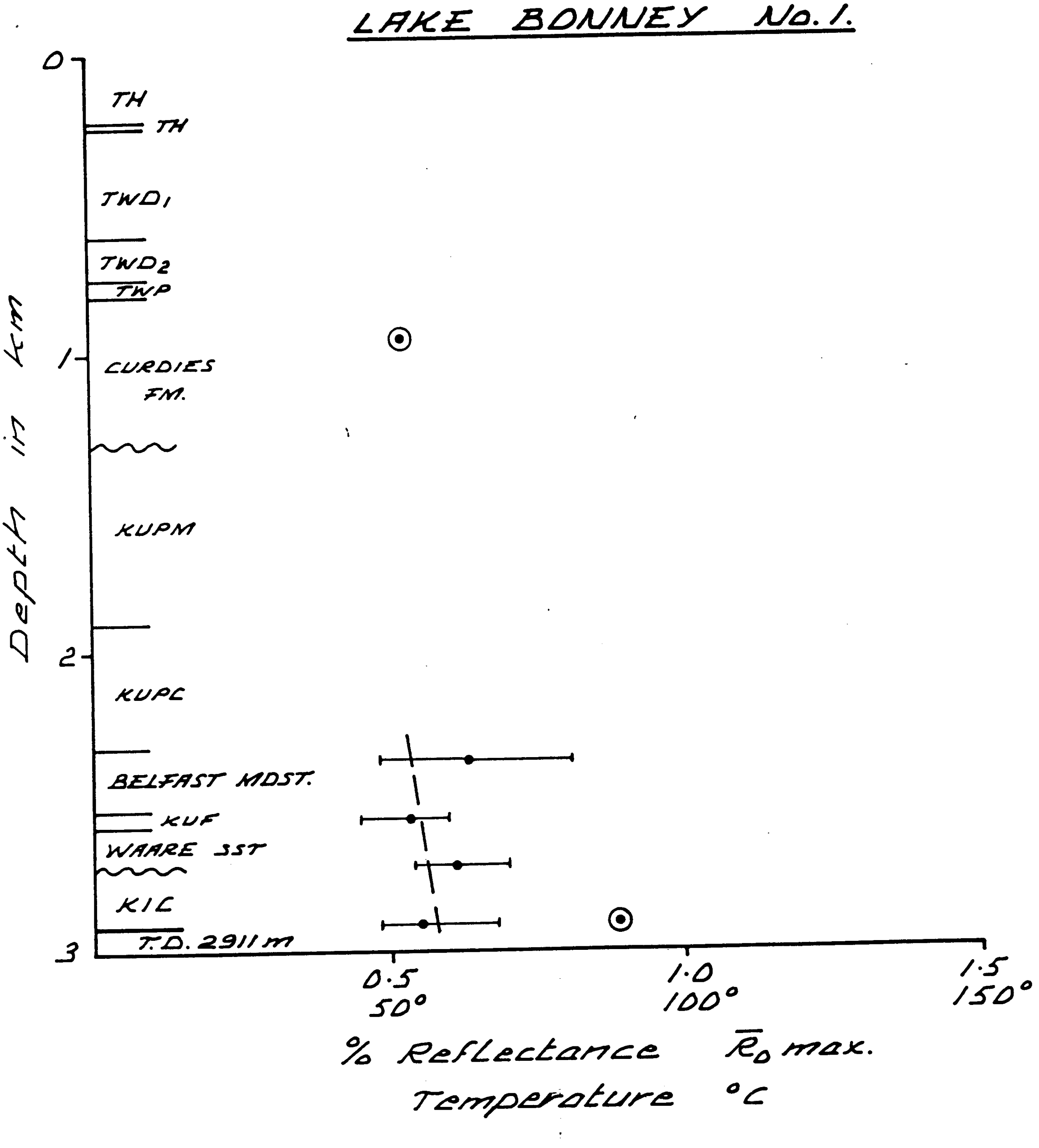

LAKE BONNEY No. 1.
0
TH
TH
TWD1
TWD2
TWP
1
CURDIES FM.
KUPM
2
KUPC
BELFAST MDST.
KUF
WAARE SST
KIC
T.D. 2911 m
3
Depth in km
0.5
50°
1.0
100°
1.5
150°
% Reflectance R̄o max.
Temperature °C

FIG. 12

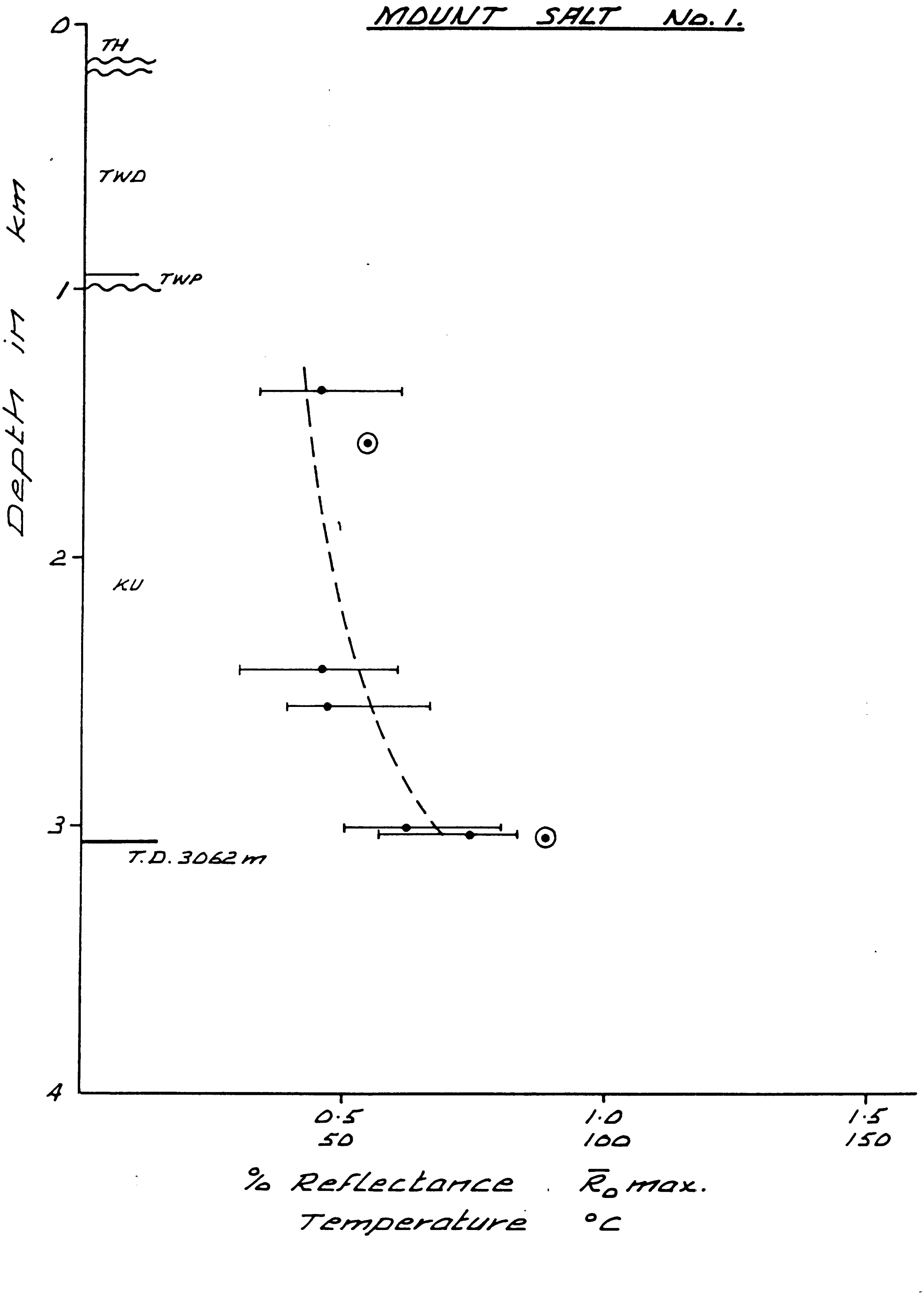

MOUNT SALT No. 1.
Depth in km
0
1
2
3
4
TH
TWD
TWP
KU
T.D. 3062 m
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 13

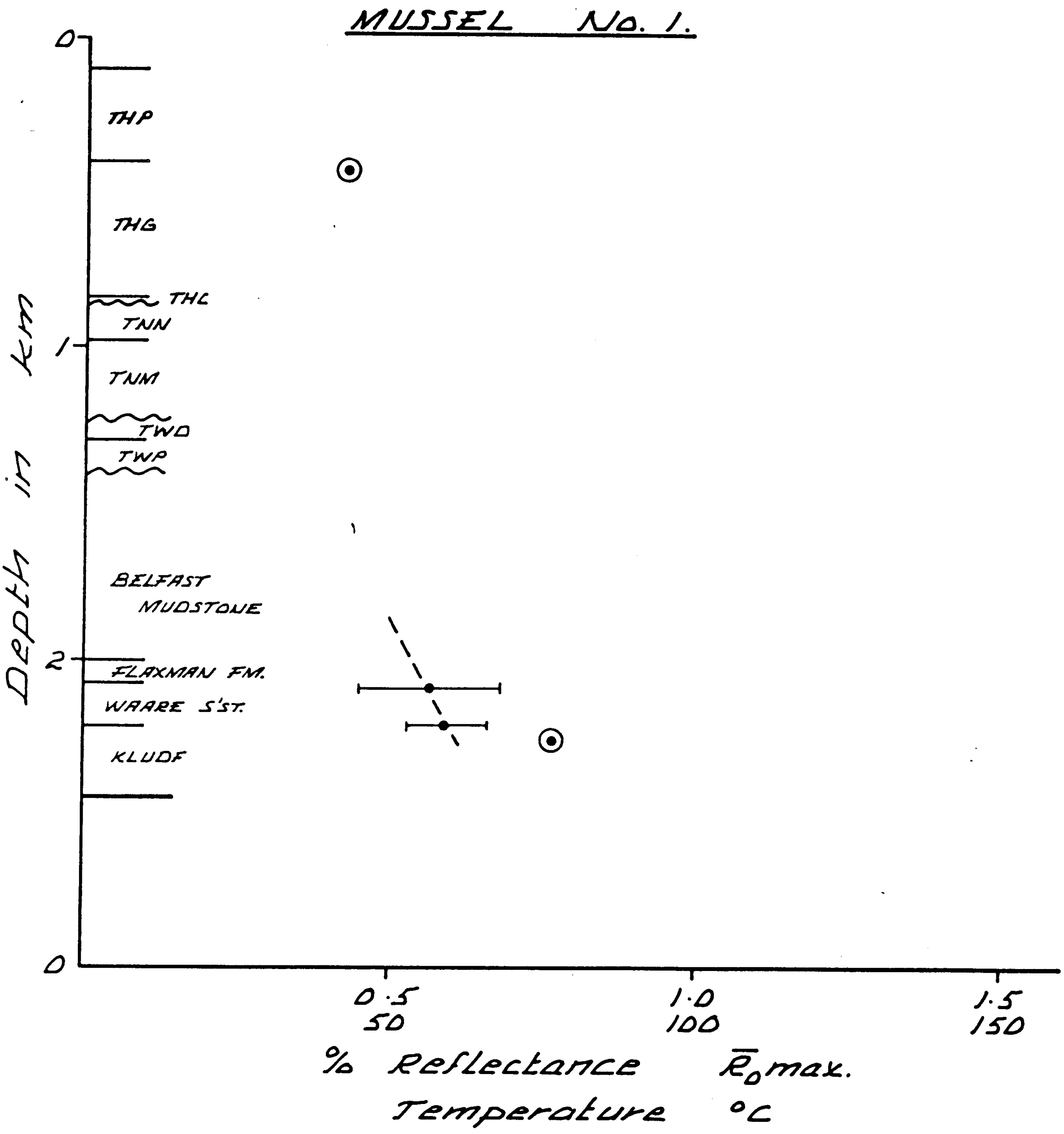

MUSSEL No. 1.
0
1
2
0
Depth in km
THP
THG
THL
TNN
TNM
TWD
TWP
BELFAST MUDSTONE
FLAXMAN FM.
WAARE S'ST.
KLUDF
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_o$max.
Temperature °C

FIG. 14

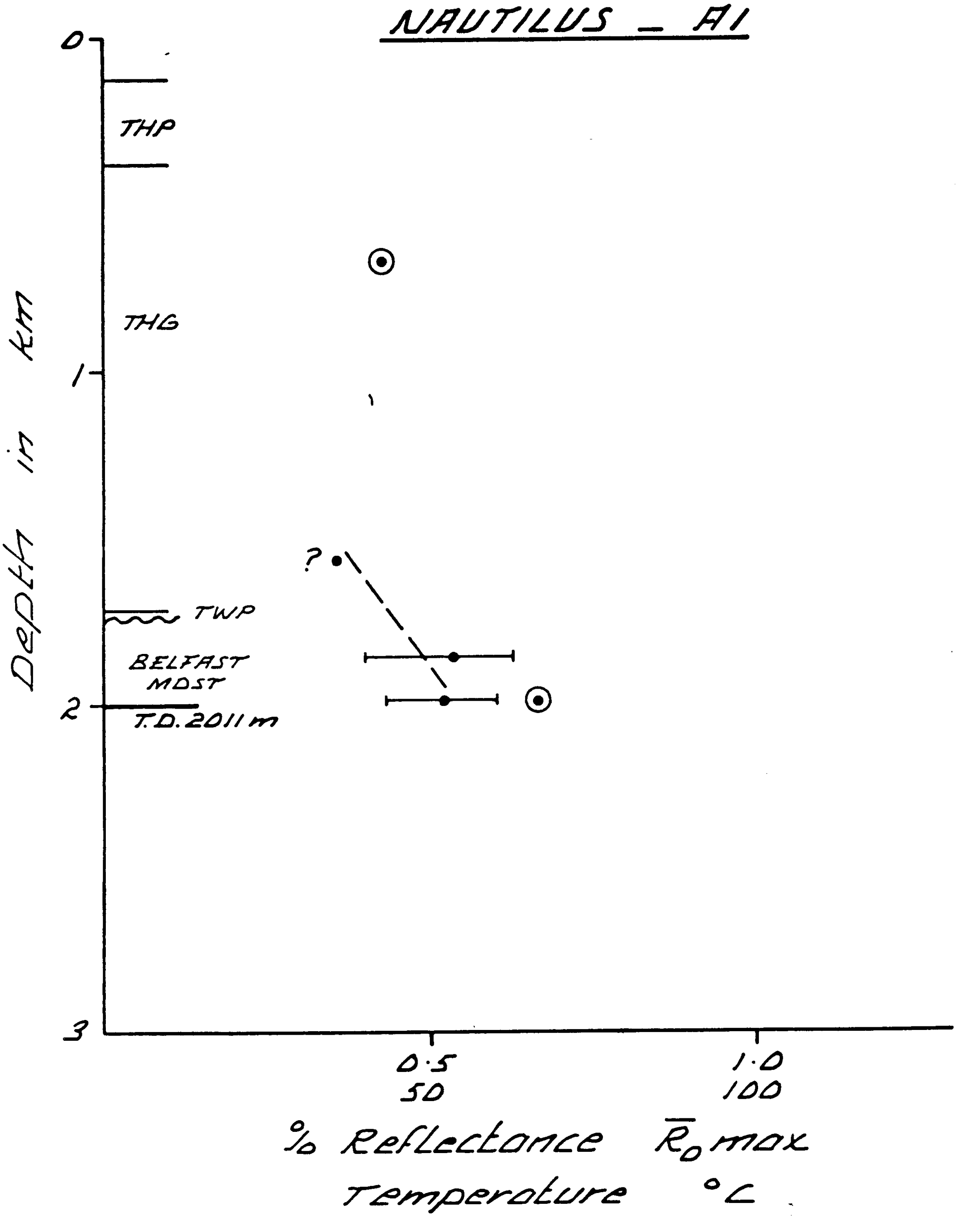

NAUTILUS - A1
0
1
2
3
Depth in km
THP
THG
TWP
BELFAST MDST
T.D. 2011 m
?
0·5
50
1·0
100
% Reflectance R̄o max
Temperature °C

FIG. 15

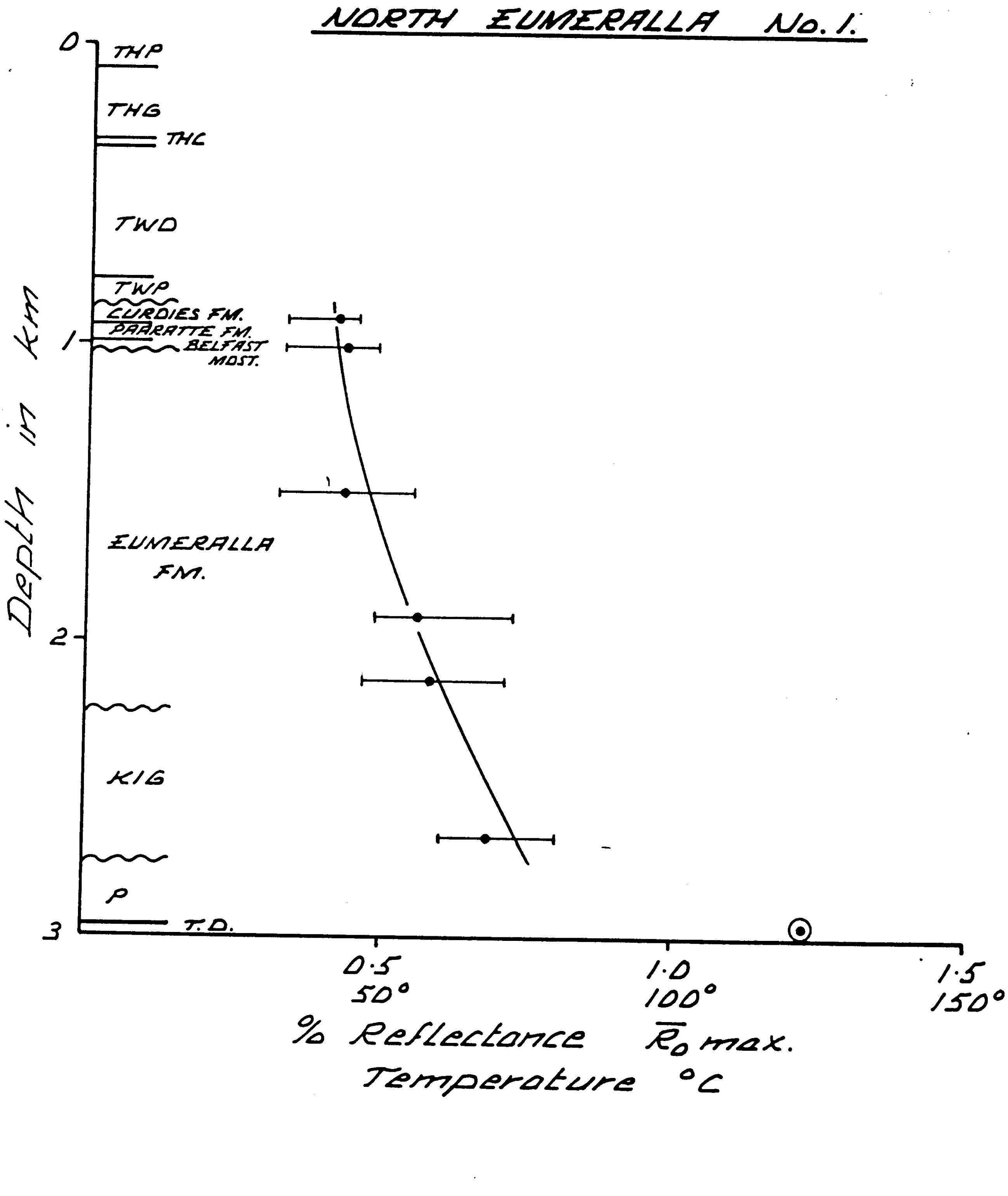

NORTH EUMERALLA No. 1.
Depth in km
0
1
2
3
THP
THG
THC
TWD
TWP
CURDIES FM.
PAARATTE FM.
BELFAST MDST.
EUMERALLA FM.
KIG
P
T.D.
0·5
50°
1·0
100°
1·5
150°
% Reflectance $\bar{R}_o$ max.
Temperature °C

FIG. 16

PECTEN No.1. – 1A.

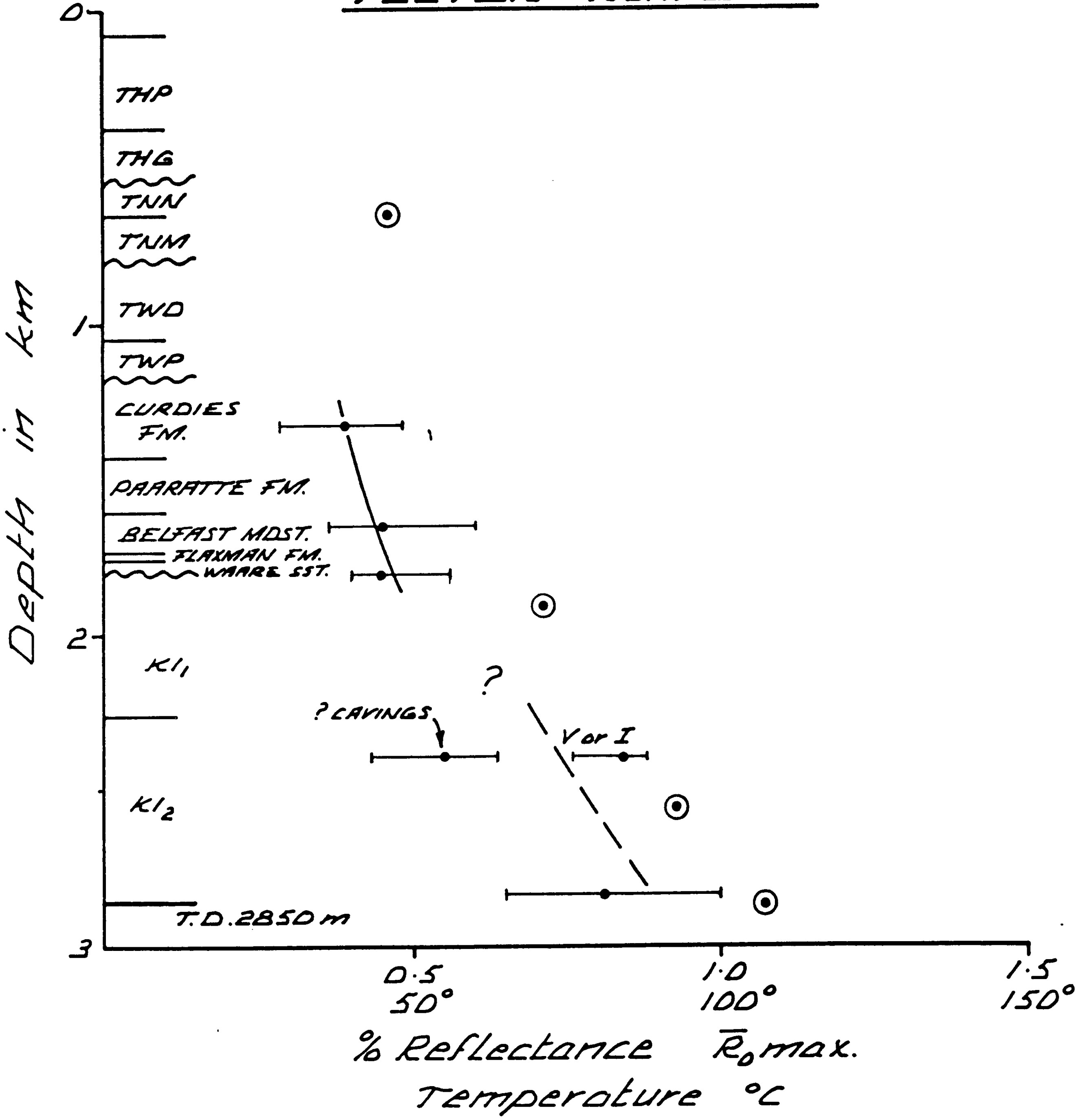


FIG. 17

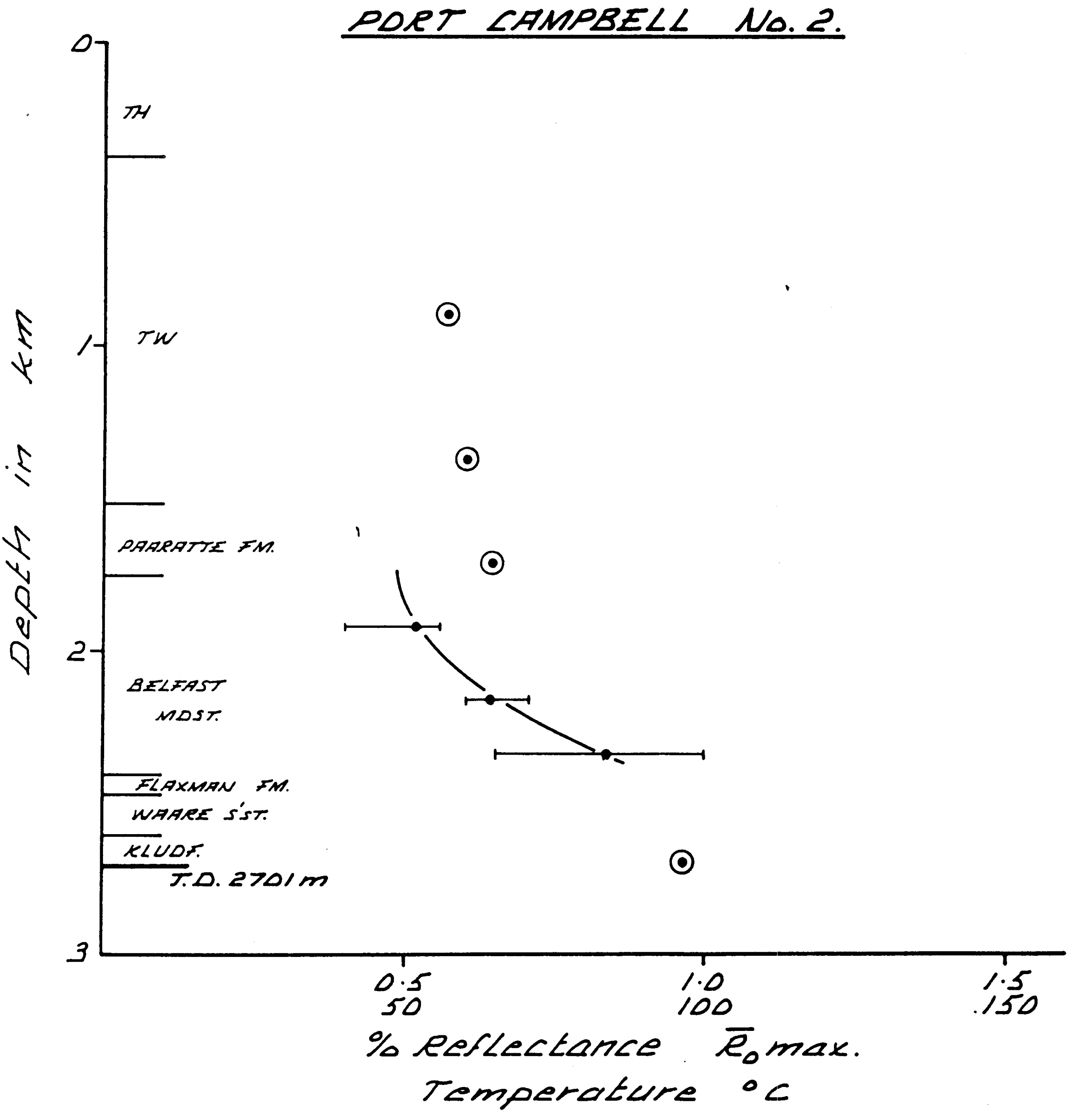

PORT CAMPBELL No. 2.
0
1
2
3
Depth in km
TH
TW
PAARATTE FM.
BELFAST MDST.
FLAXMAN FM.
WAARE S'ST.
KLUDF.
T.D. 2701 m
0·5
50
1·0
100
1·5
150
% Reflectance $\overline{R}_0$ max.
Temperature °C

FIG. 18

PORTLAND No. 3.

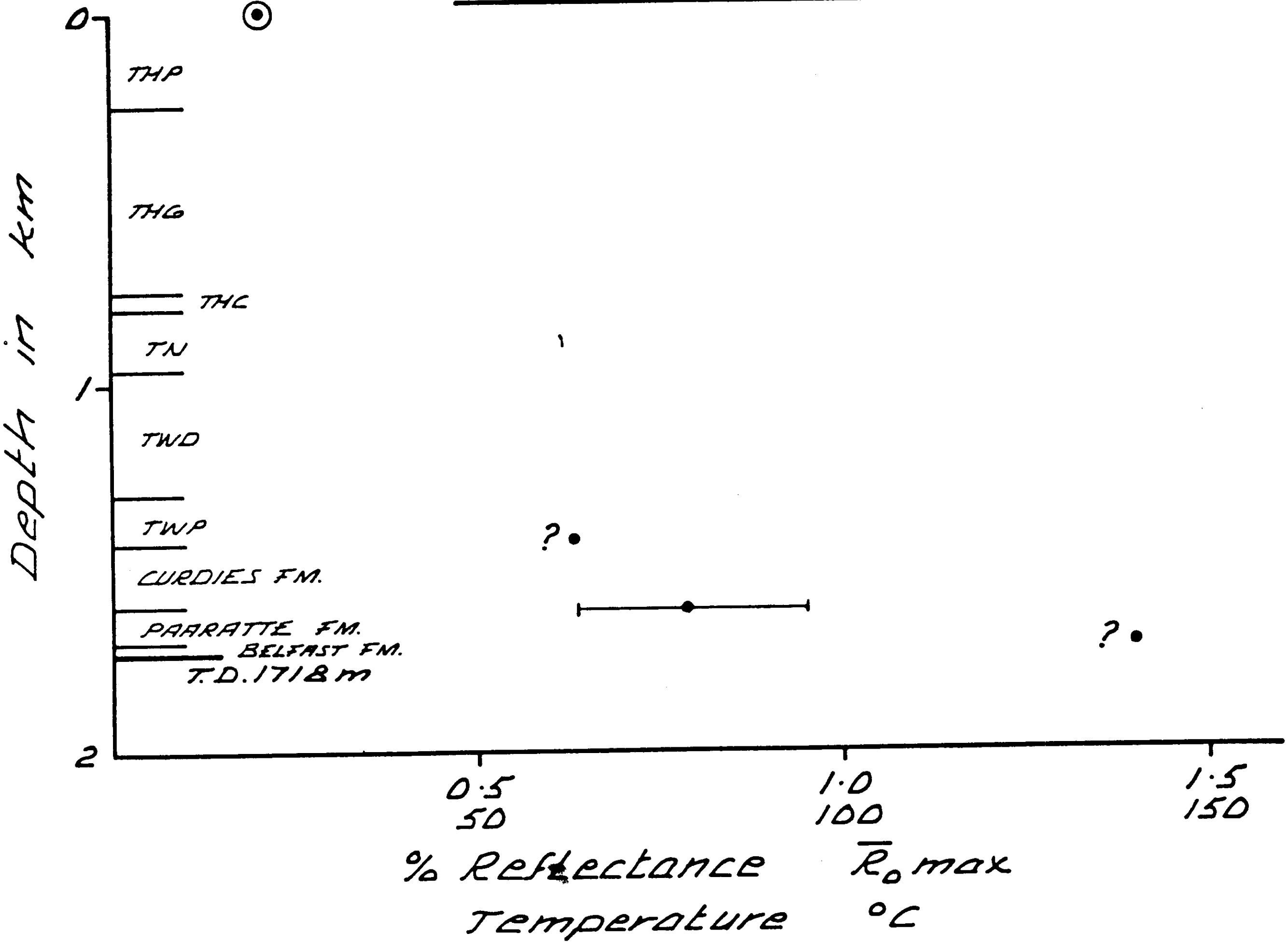


FIG. 19

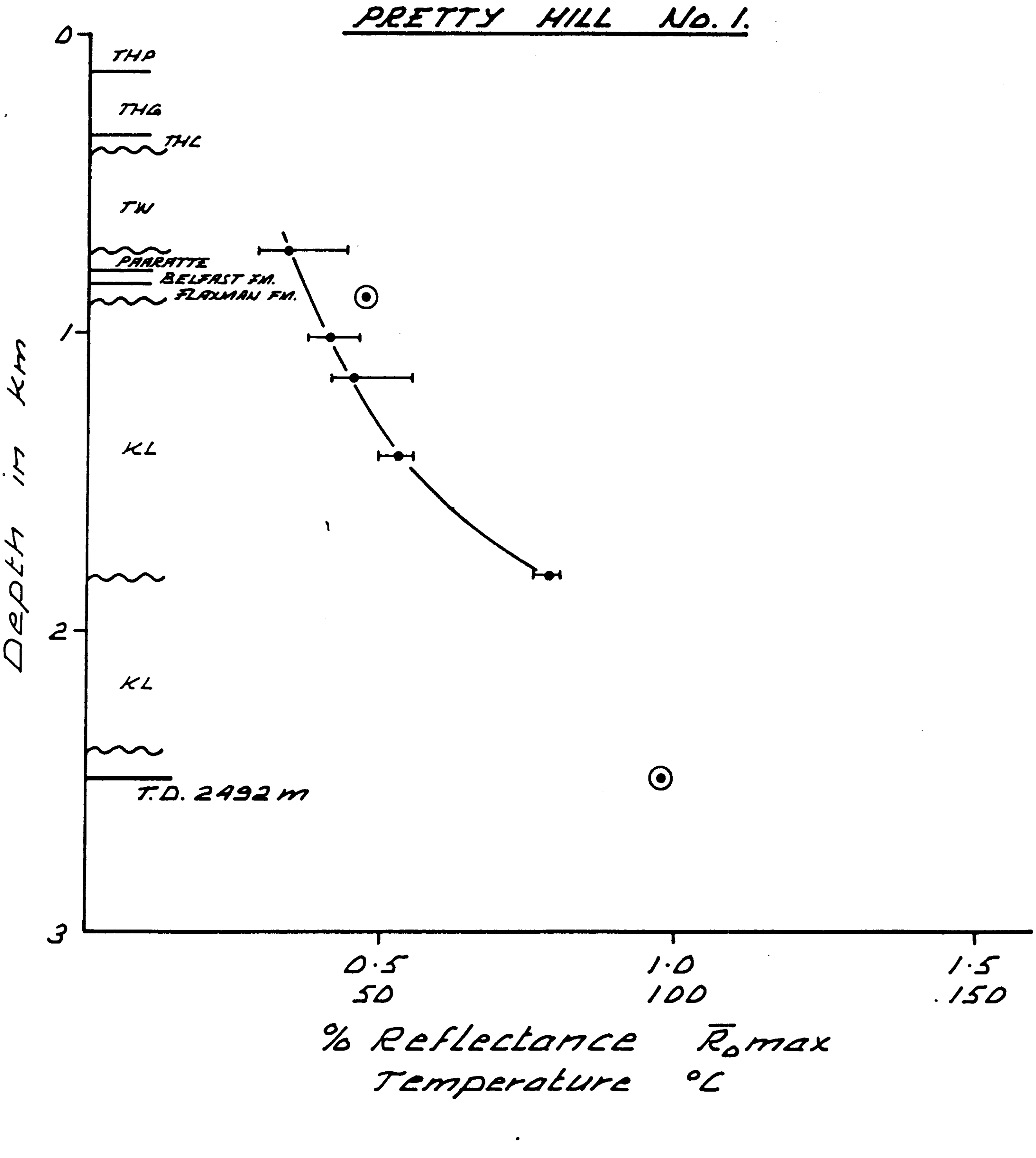

PRETTY HILL No. 1.
0
1
2
3
Depth in Km
THP
THG
THC
TW
PAARATTE
BELFAST FM.
FLAXMAN FM.
KL
KL
T.D. 2492 m
0·5
50
1·0
100
1·5
150
% Reflectance $\bar{R}_o$max
Temperature °C

FIG. 20

ROWANS No. 1.

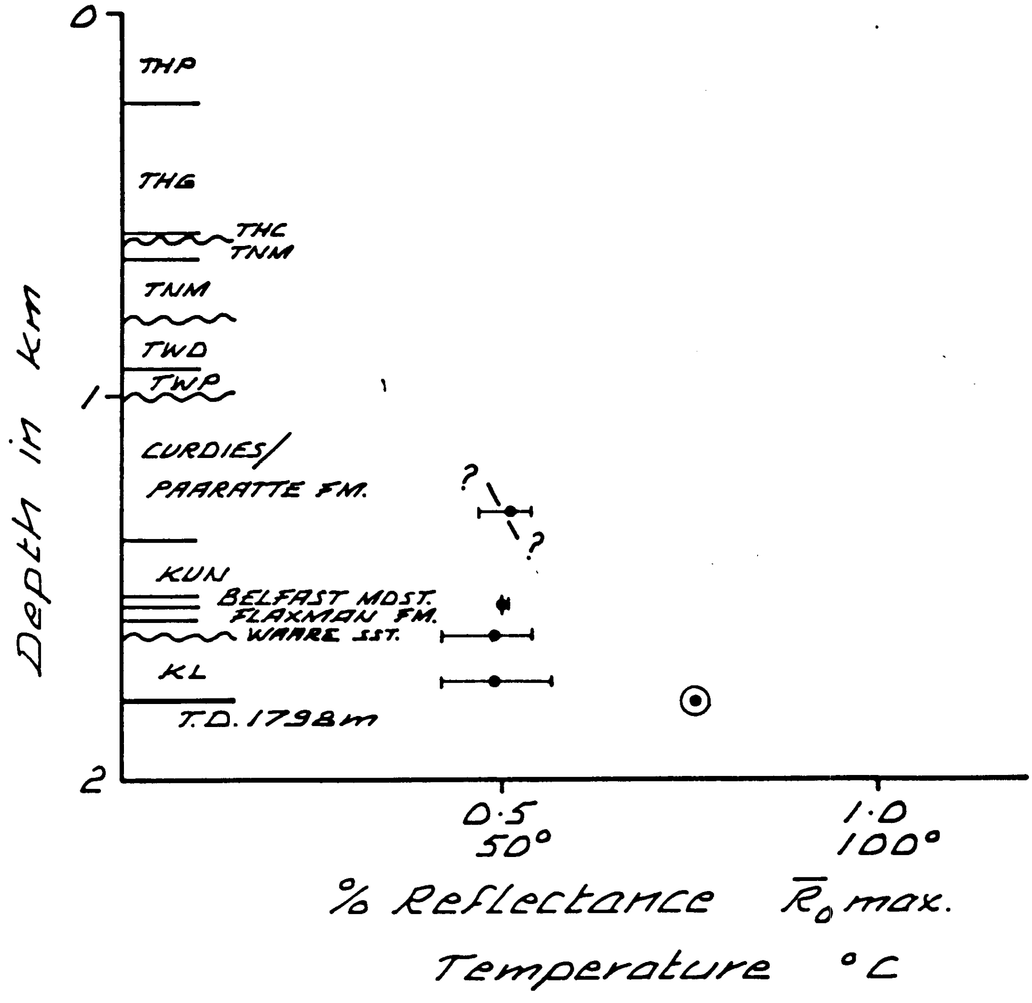
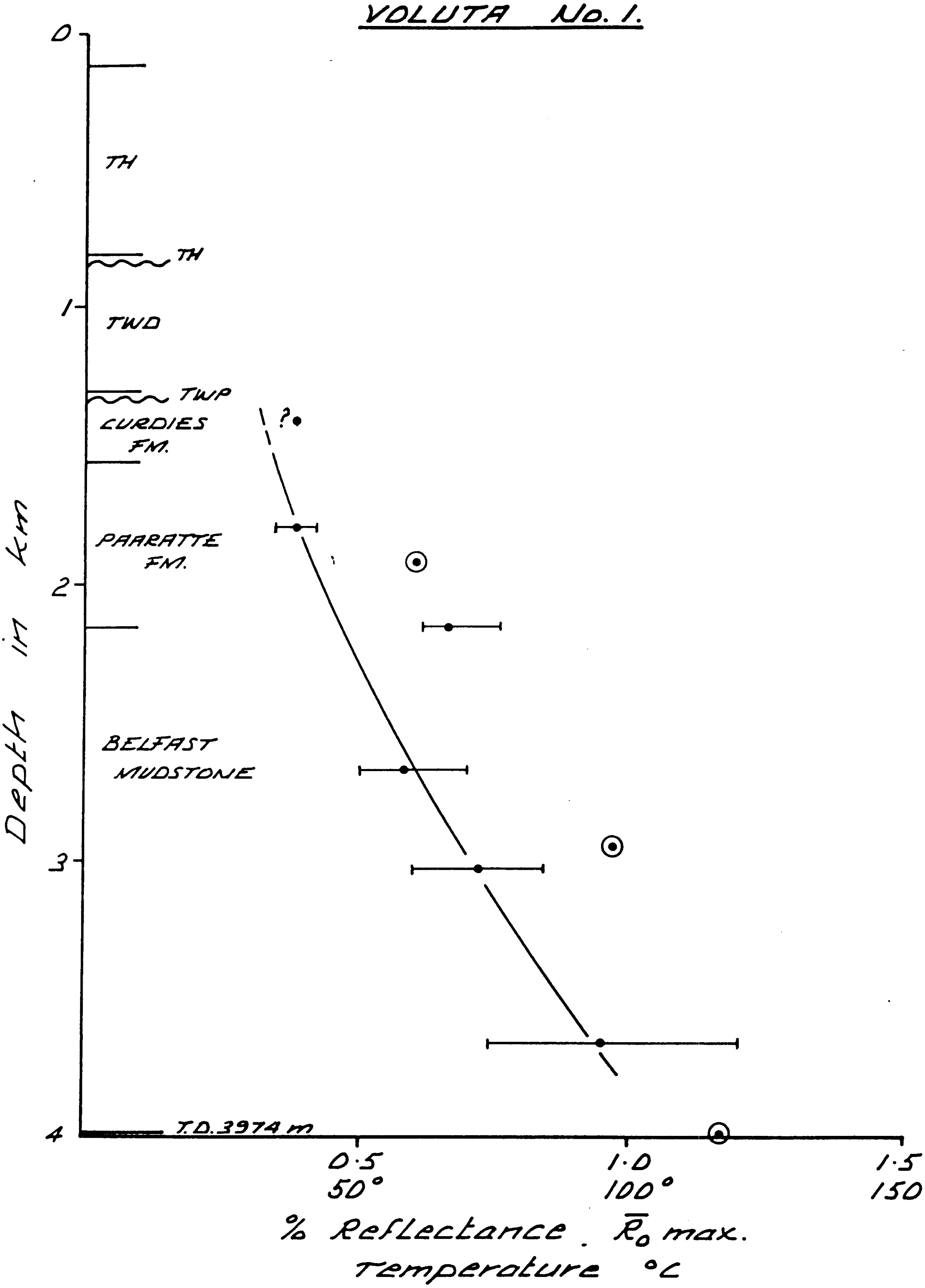
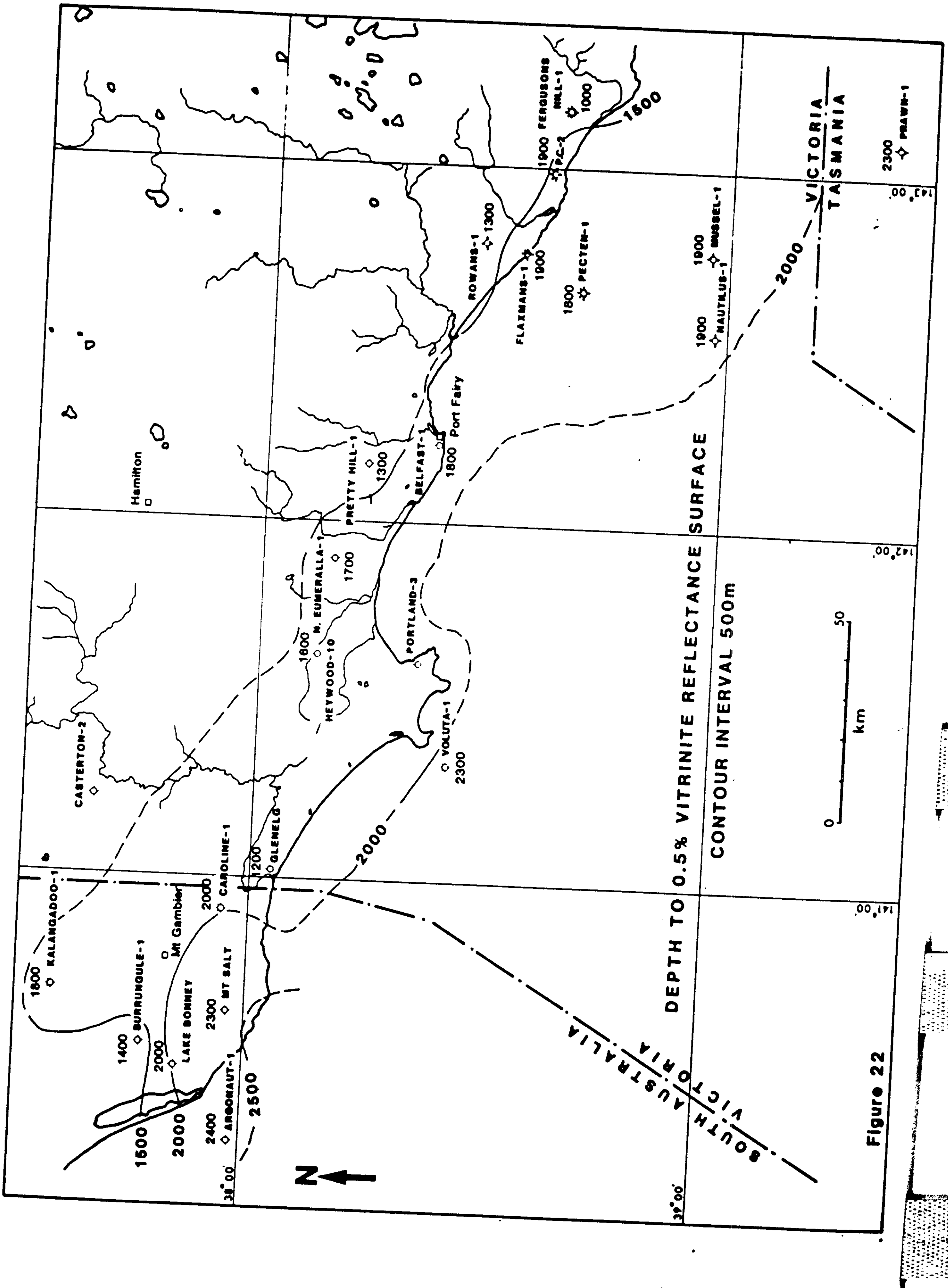


FIG. 21

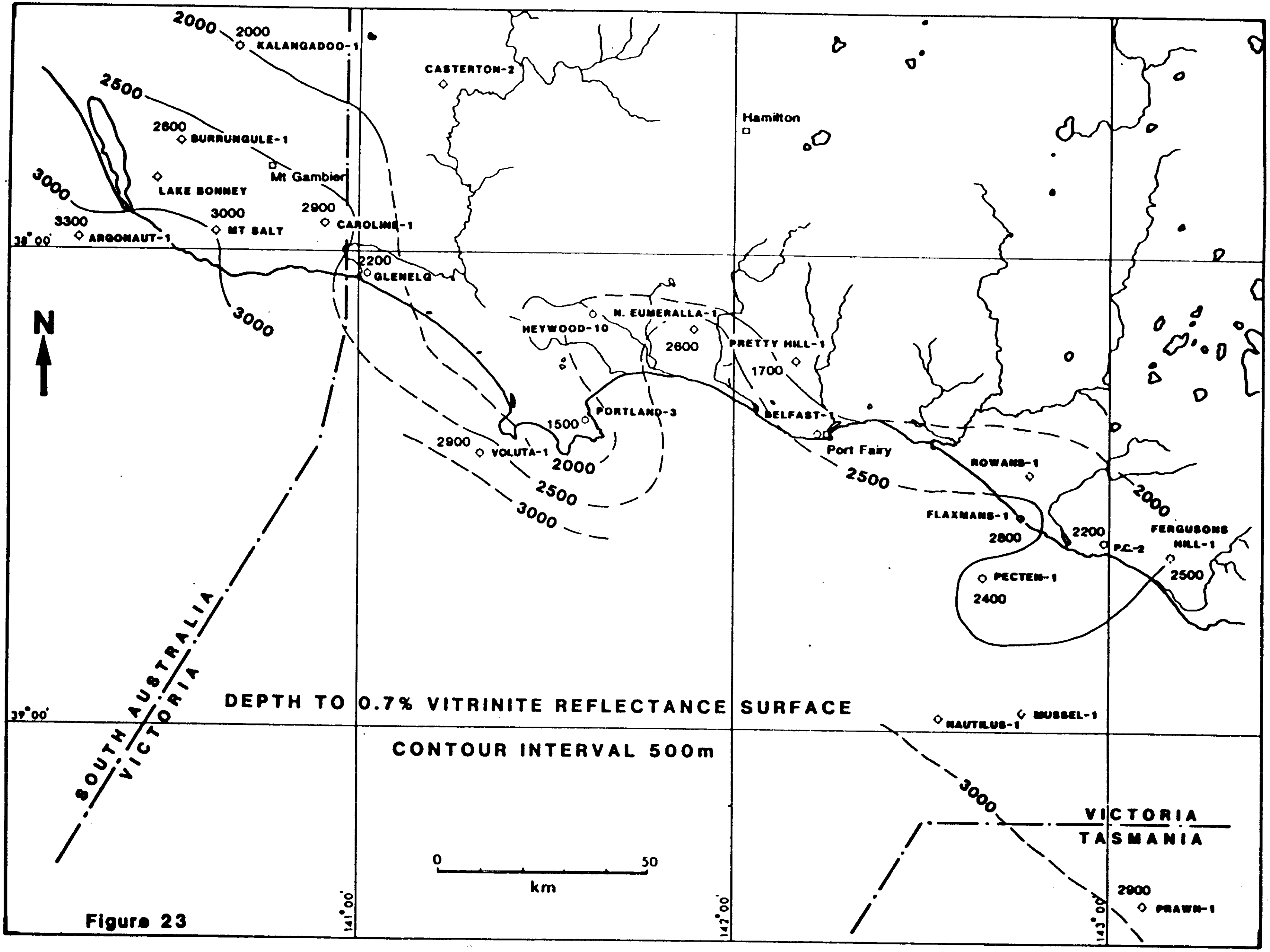

VOLUTA No. 1.
0
1
2
3
4
Depth in km
TH
TH
TWD
TWP
CURDIES FM.
PAARATTE FM.
BELFAST MUDSTONE
T.D. 3974 m
?
0·5
50°
1·0
100°
1·5
150
% Reflectance R̄o max.
Temperature °C



DEPTH TO 0.5% VITRINITE REFLECTANCE SURFACE

CONTOUR INTERVAL 500m

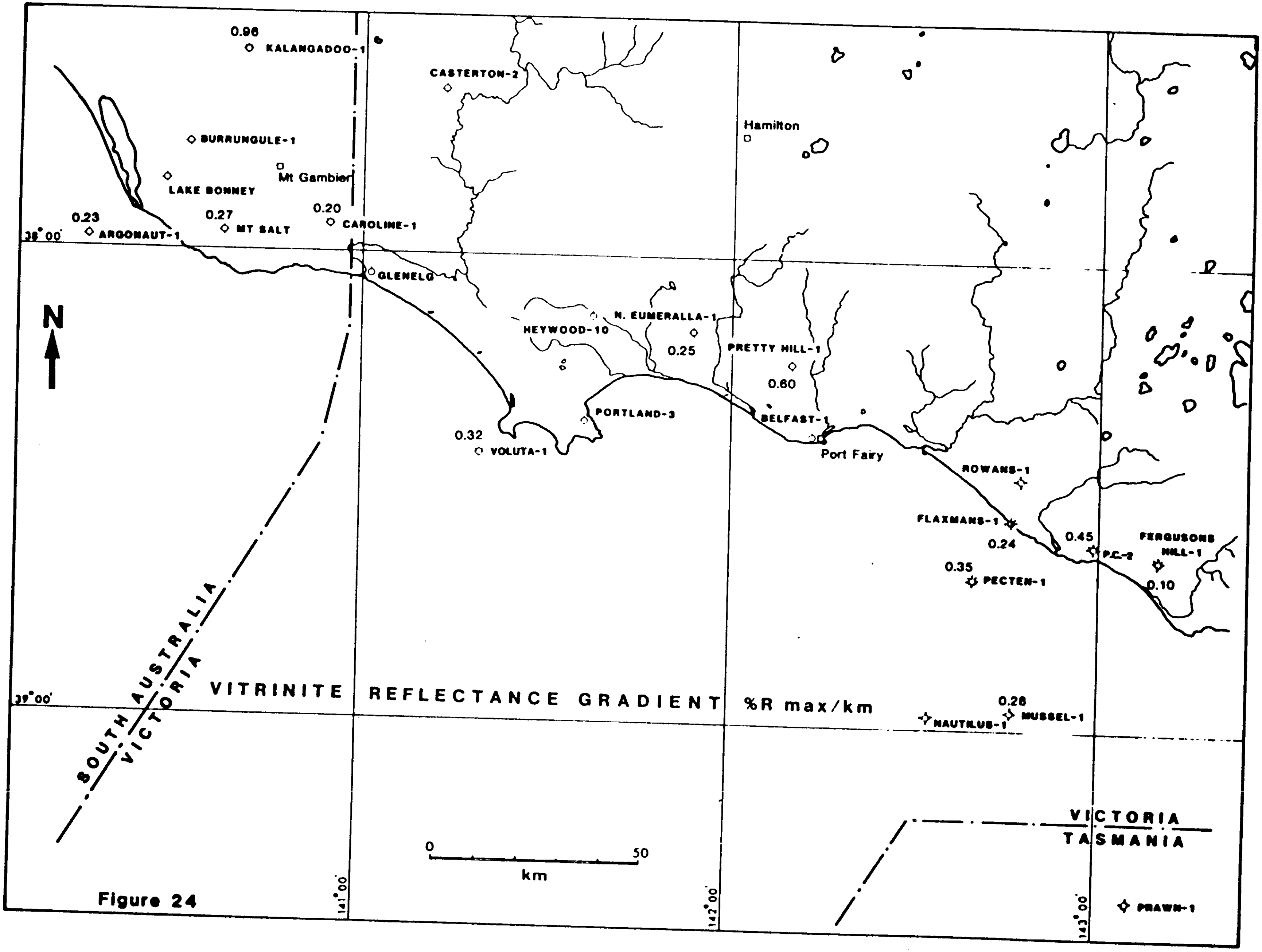
Figure 22



DEPTH TO 0.7% VITRINITE REFLECTANCE SURFACE

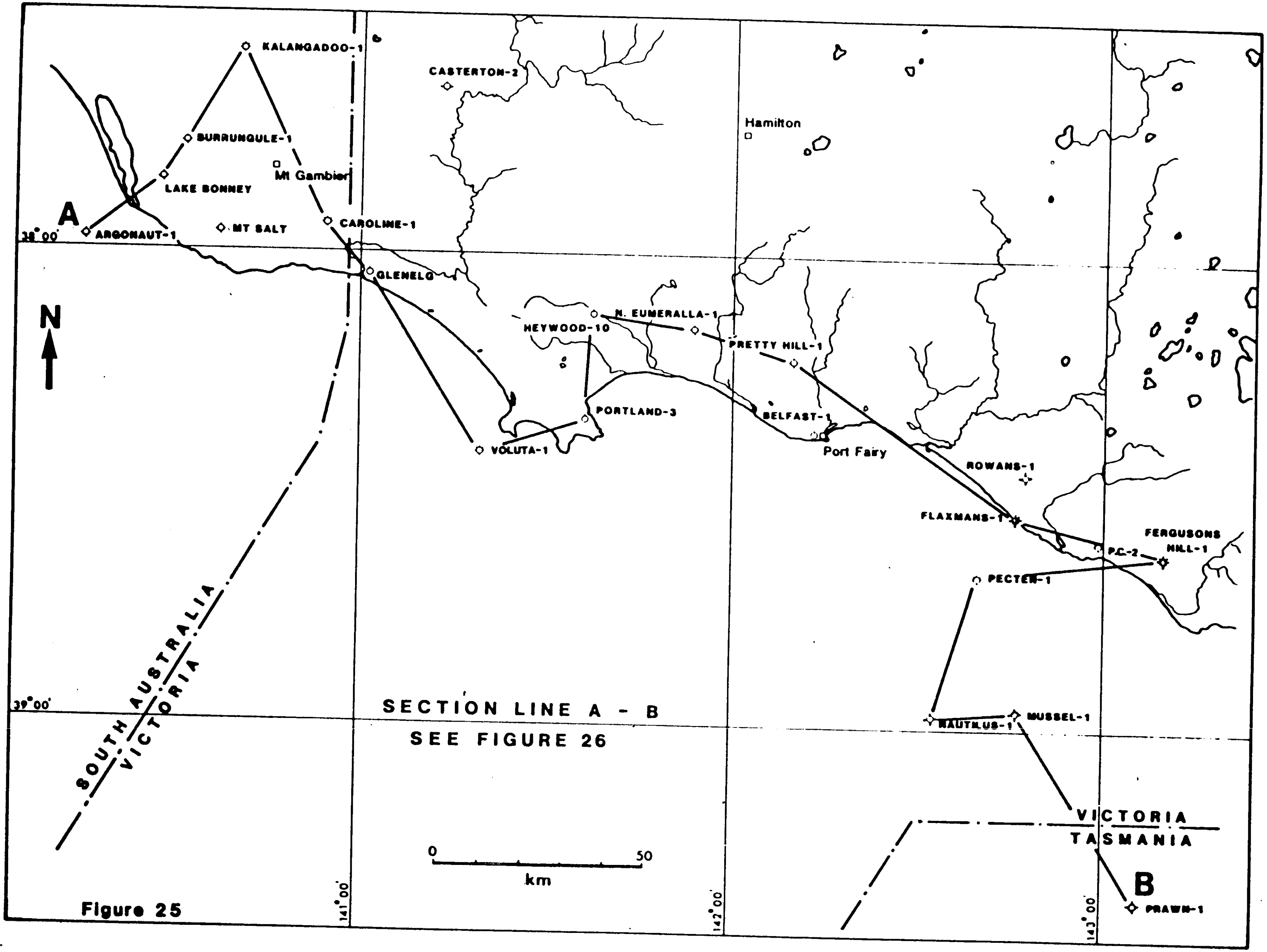
CONTOUR INTERVAL 500m

Figure 23



VITRINITE REFLECTANCE GRADIENT %R max/km

Figure 24



A
KALANGADOO-1
BURRUNGULE-1
Mt Gambier
LAKE BONNEY
MT SALT
ARGONAUT-1
CAROLINE-1
GLENELG
CASTERTON-2
Hamilton
N. EUMERALLA-1
HEYWOOD-10
PRETTY HILL-1
PORTLAND-3
VOLUTA-1
BELFAST-1
Port Fairy
ROWANS-1
FLAXMANS-1
FERGUSONS HILL-1
P.C.-2
PECTEN-1
NAUTILUS-1
MUSSEL-1
PRAWN-1
B
N
38°00'
39°00'
141°00'
142°00'
143°00'
SOUTH AUSTRALIA
VICTORIA
VICTORIA
TASMANIA
SECTION LINE A - B
SEE FIGURE 26
0
50
km

Figure 25

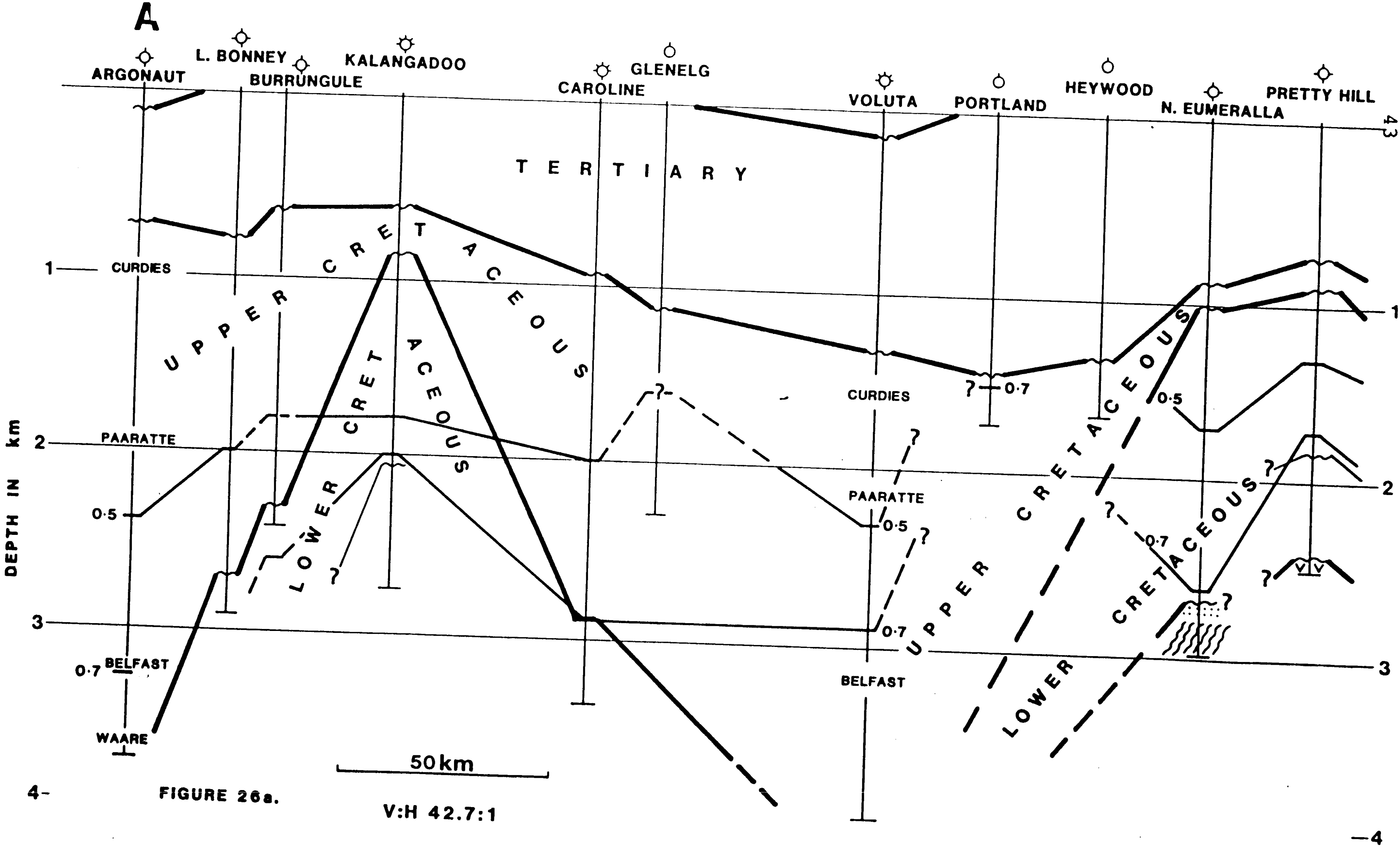

A
ARGONAUT
L. BONNEY
BURRUNGULE
KALANGADOO
CAROLINE
GLENELG
VOLUTA
PORTLAND
HEYWOOD
N. EUMERALLA
PRETTY HILL
TERTIARY
UPPER CRETACEOUS
LOWER CRETACEOUS
UPPER CRETACEOUS
LOWER CRETACEOUS
CURDIES
PAARATTE
BELFAST
WAARE
0·5
0·7
?
DEPTH IN km
1
2
3
4
50km
V:H 42.7:1

FIGURE 26a.

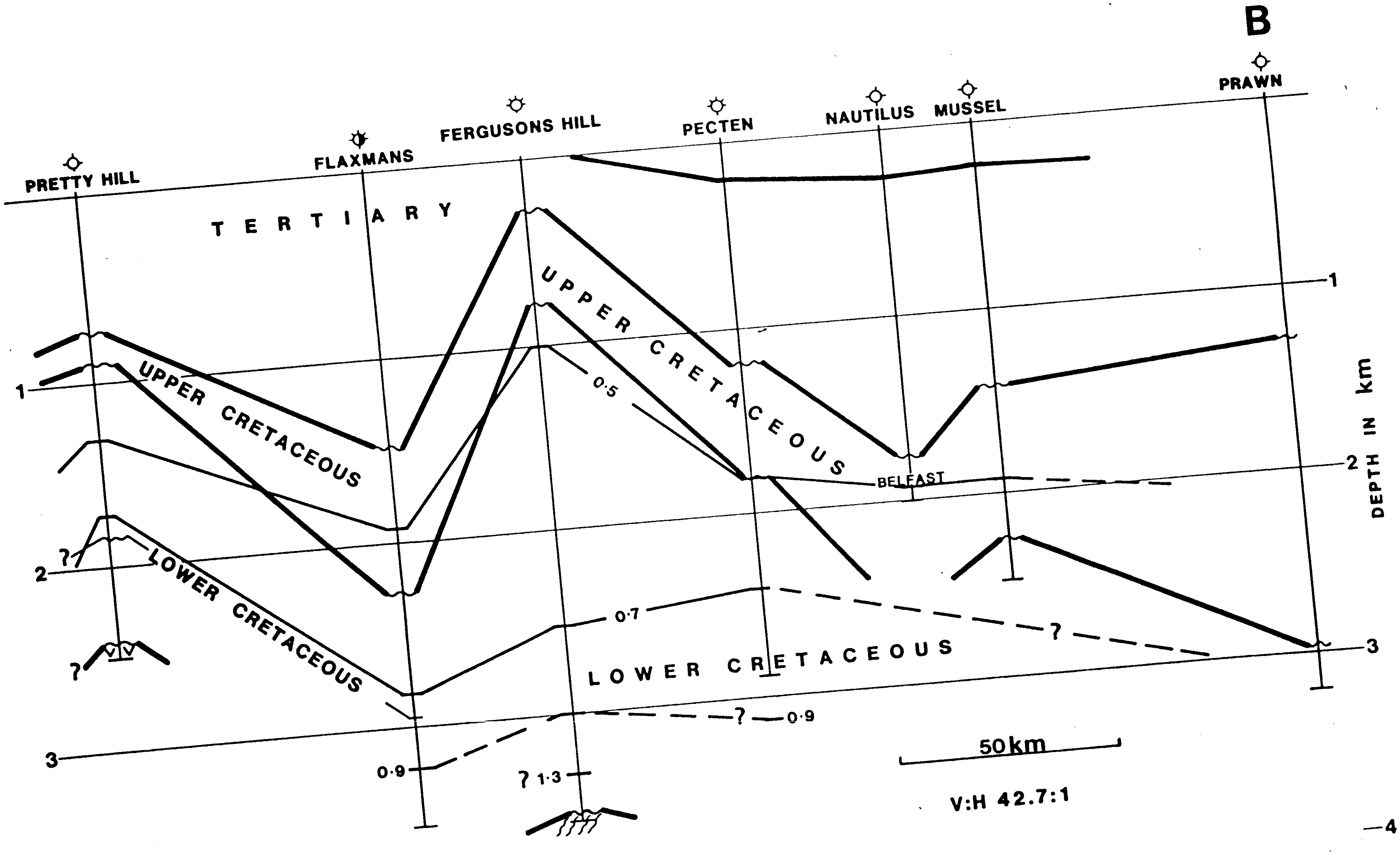

B
PRETTY HILL
FLAXMANS
FERGUSONS HILL
PECTEN
NAUTILUS
MUSSEL
PRAWN
TERTIARY
UPPER CRETACEOUS
UPPER CRETACEOUS
LOWER CRETACEOUS
LOWER CRETACEOUS
BELFAST
0·5
0·7
0·9
0·9
? 1·3
?
DEPTH IN km
1
2
3
4
50km
V:H 42.7:1

FIGURE 26b.

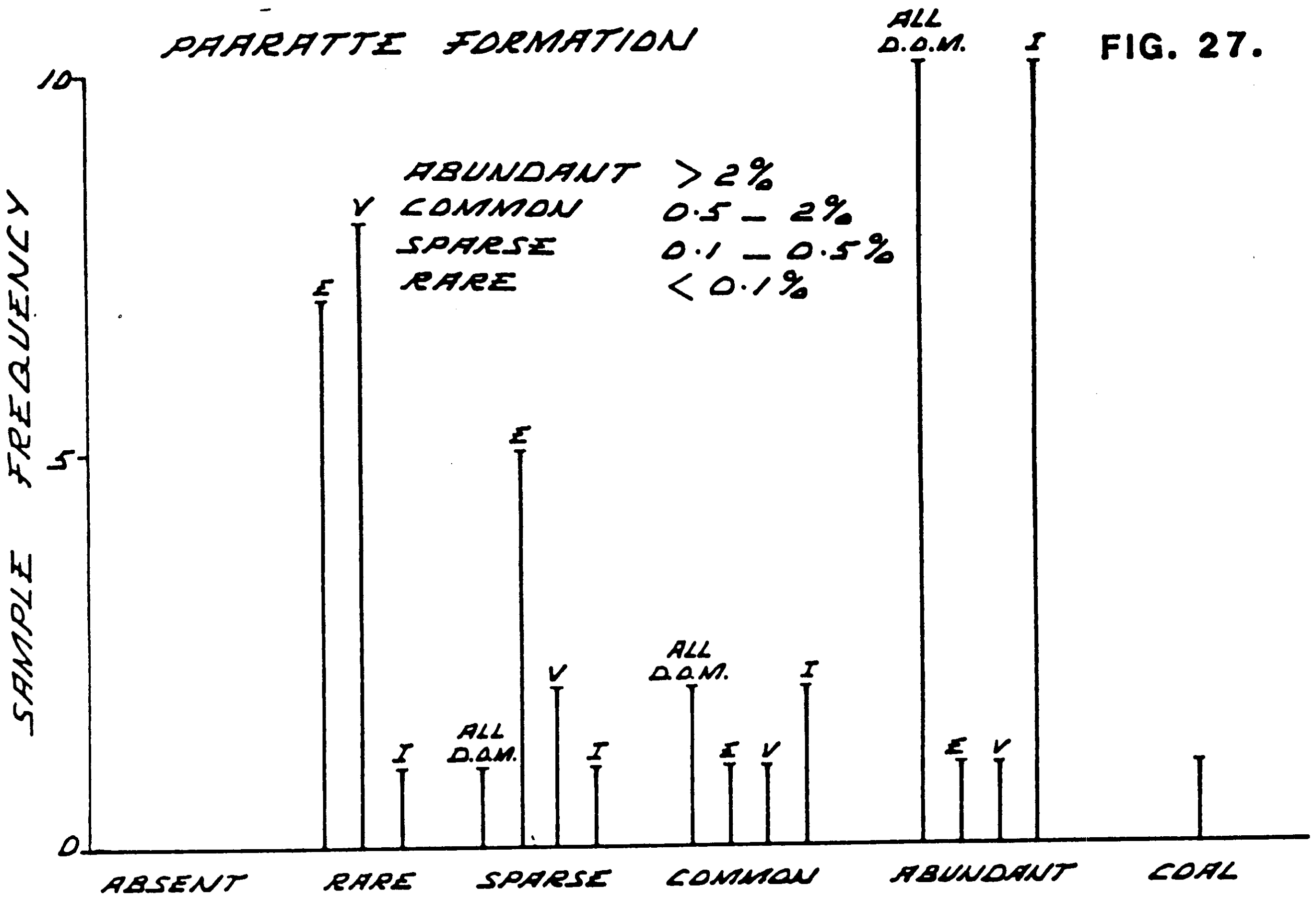

PAARATTE FORMATION
ABUNDANT >2%
COMMON 0·5 – 2%
SPARSE 0·1 – 0·5%
RARE <0·1%
SAMPLE FREQUENCY
10
5
0
ABSENT
RARE
SPARSE
COMMON
ABUNDANT
COAL
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I

FIG. 27.

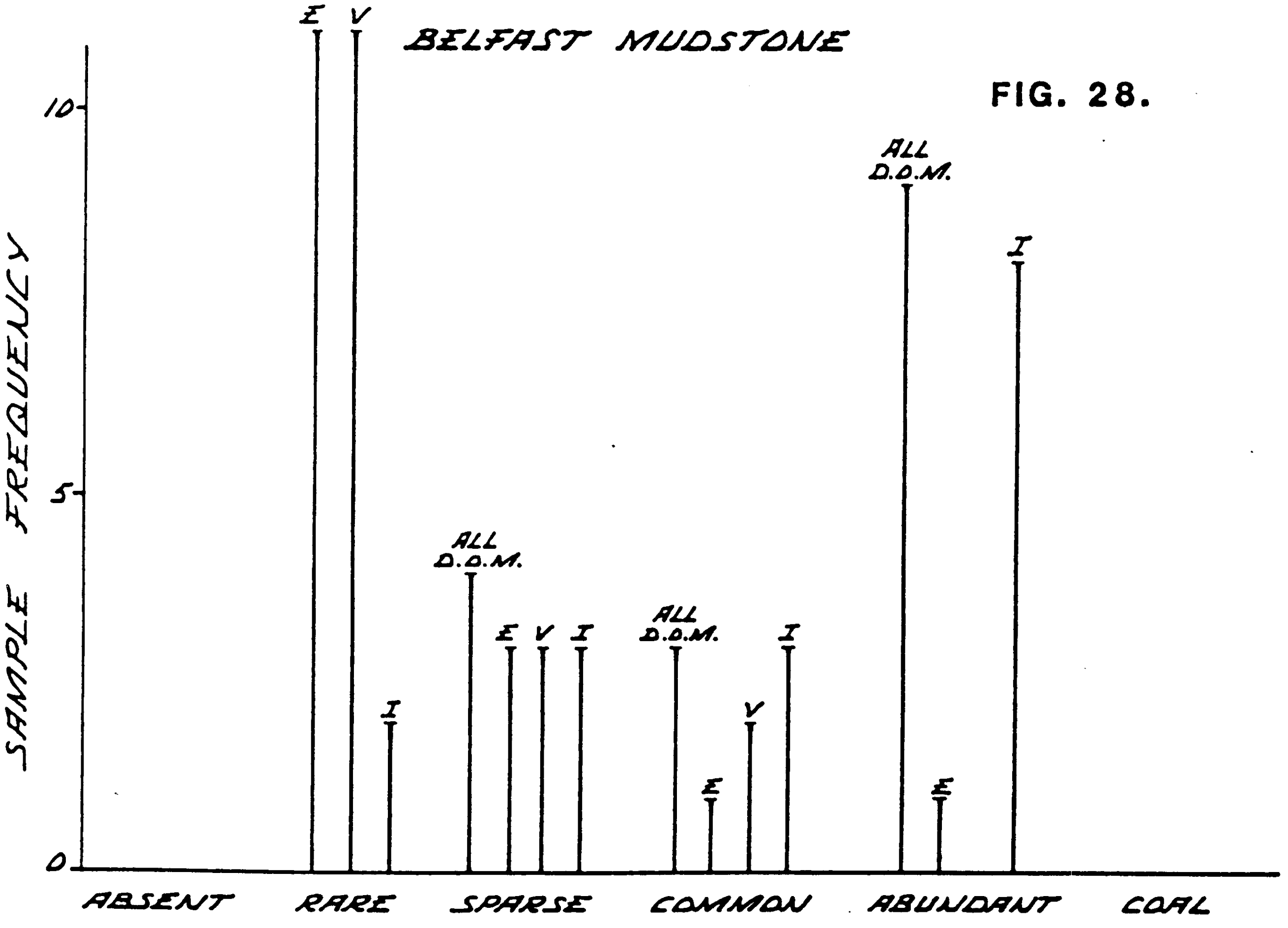

BELFAST MUDSTONE
SAMPLE FREQUENCY
10
5
0
ABSENT
RARE
SPARSE
COMMON
ABUNDANT
COAL
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
I

FIG. 28.

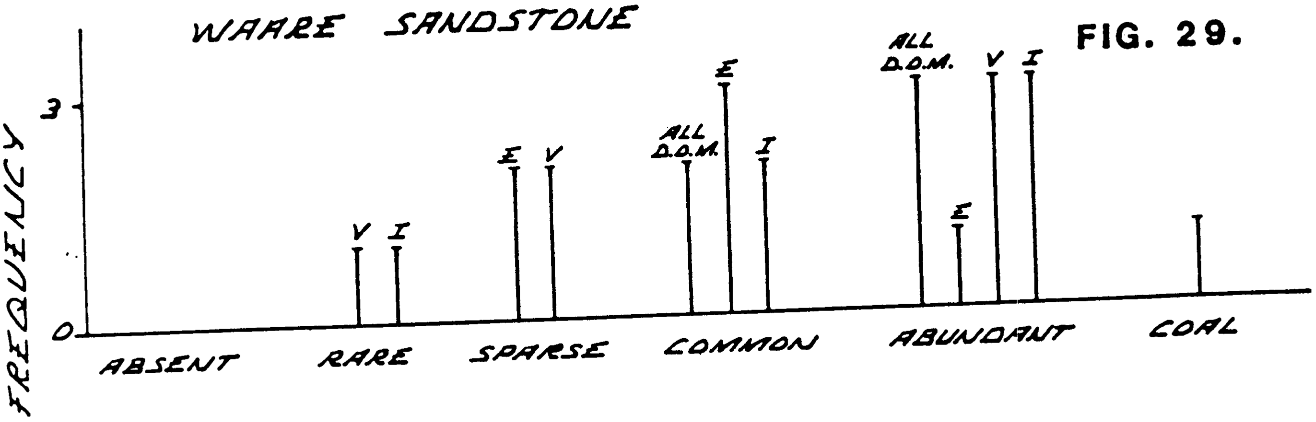


FIG. 29.

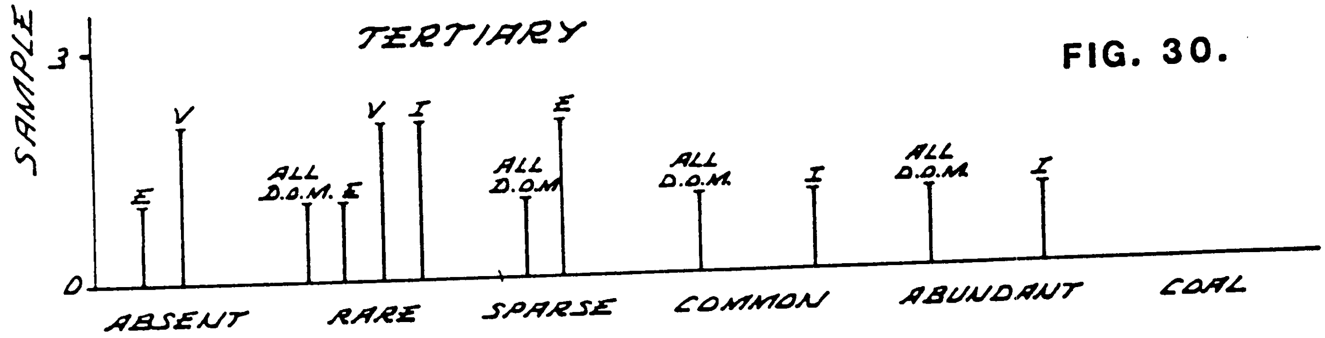


FIG. 30.

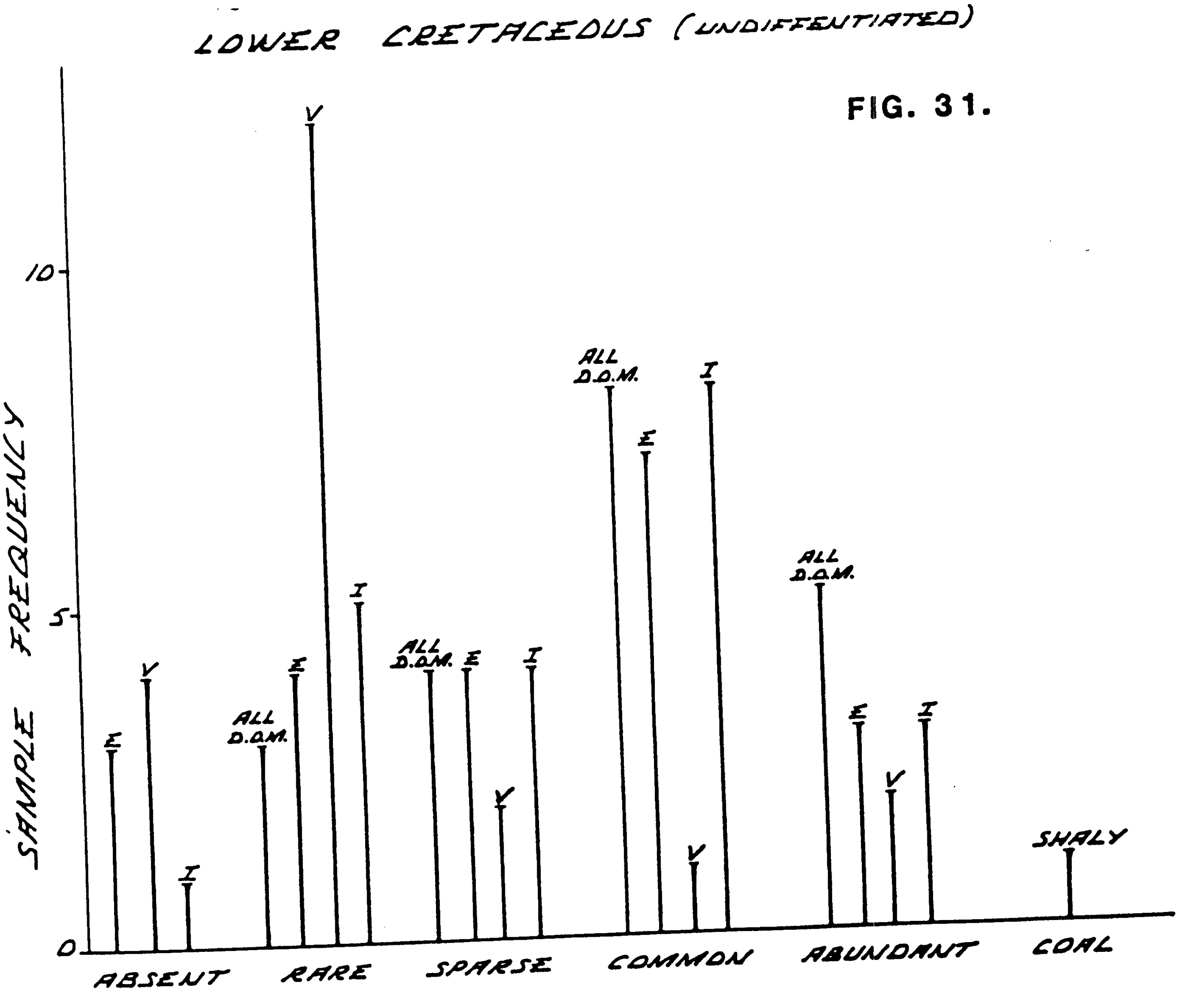


FIG. 31.

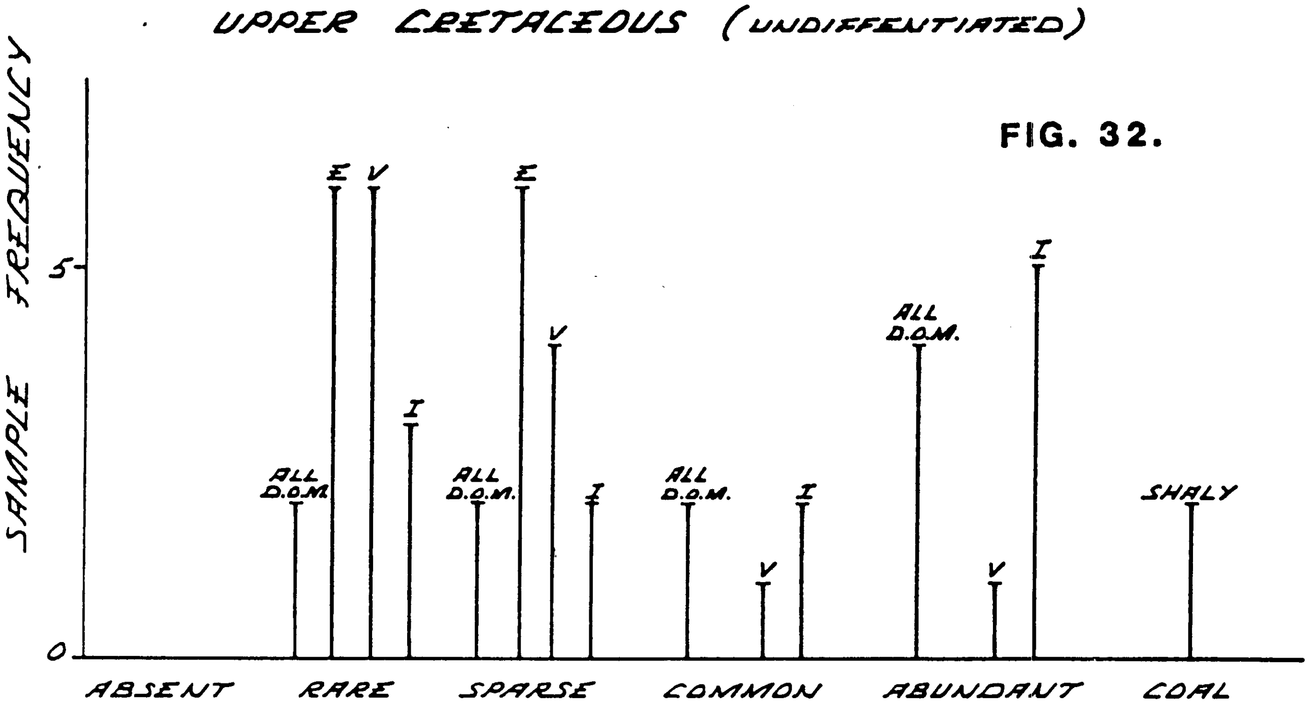

UPPER CRETACEOUS (UNDIFFENTIATED)
SAMPLE FREQUENCY
5
0
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
V
I
ALL D.O.M.
V
I
SHALY
ABSENT
RARE
SPARSE
COMMON
ABUNDANT
COAL

FIG. 32.

FIG. 33.

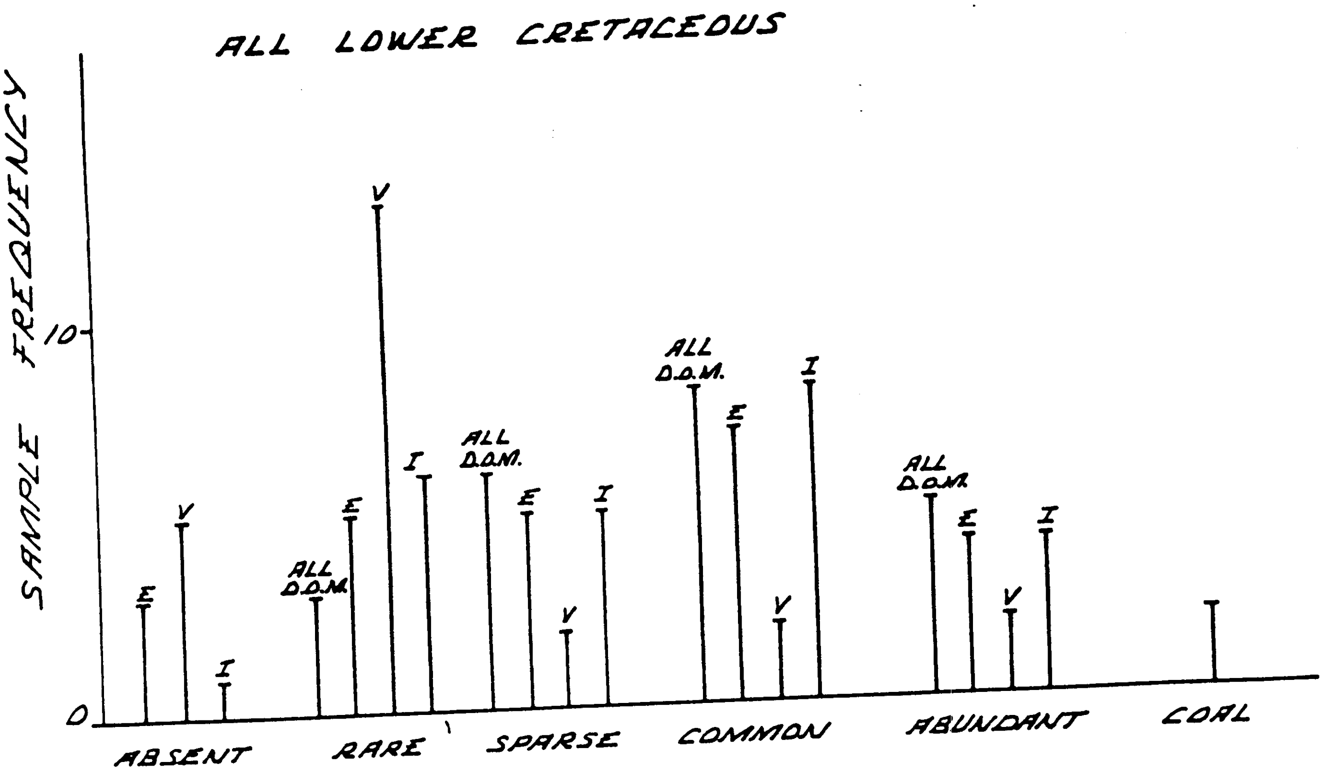
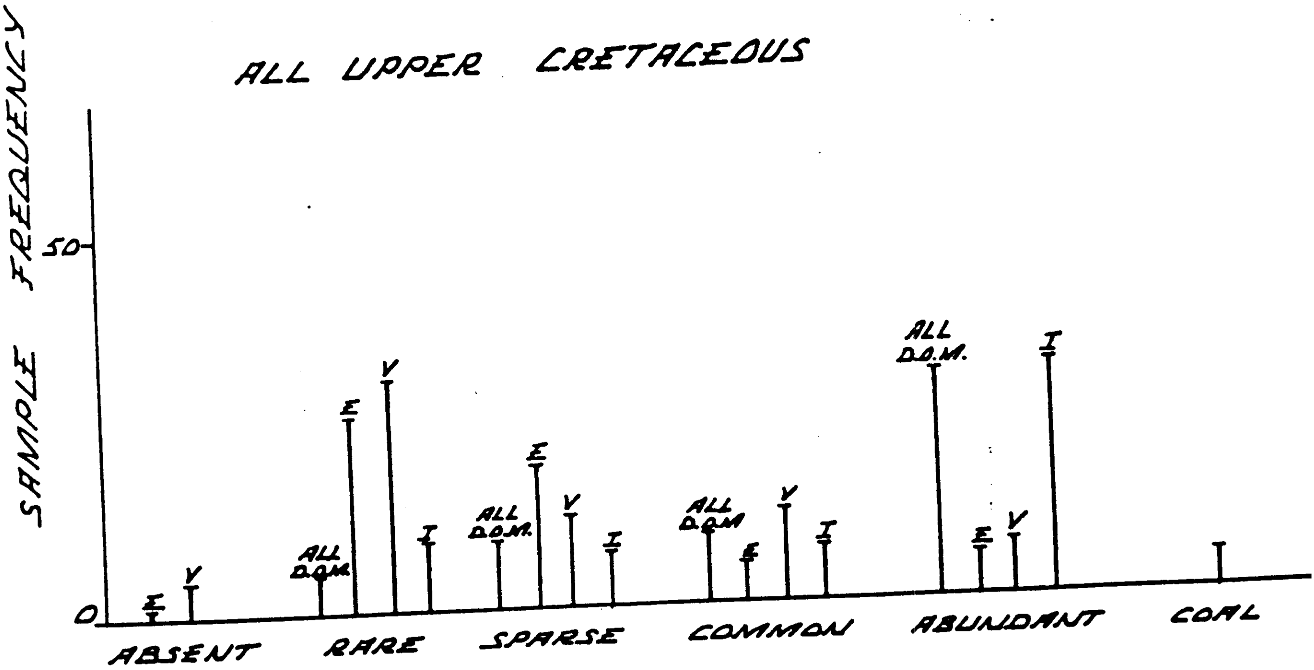

ALL LOWER CRETACEOUS
SAMPLE FREQUENCY
10
0
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ABSENT
RARE
SPARSE
COMMON
ABUNDANT
COAL

FIG. 34.


ALL UPPER CRETACEOUS
SAMPLE FREQUENCY
50
0
E
V
ALL D.O.M.
E
V
I
ALL D.O.M.
E
V
I
ALL D.O.M
E
V
I
ALL D.O.M.
E
V
I
ABSENT
RARE
SPARSE
COMMON
ABUNDANT
COAL

VITRINITE REFLECTANCE AND EXINITE FLUORESCENCE DATA, TOGETHER WITH BRIEF SAMPLE DESCRIPTIONS AND SUMMARIES FOR EACH WELL.

Argonaut No. 1

The samples are mostly of sand-dominated lithologies and the organic matter in them may not be typical of finer grained parts of the sequence. All the samples contain abundant dispersed organic matter, but this is chiefly composed of massive inertinite. The vitrinite populations are, in general, poorly defined, as in Plates 1 and 2, or absent. Many of the samples contain shell fragments annd appear to have been extensively reworked. Much of the inertinite may have had an origin through the oxidation of humified woody tissue. The low exinite content may be associated with reworking and oxidation.

The better defined vitrinite population in the deepest sample, allows the definition of vitrinite populations in most of the other samples. The depth - reflectance profile indicates that the well terminated close to the peak oil generation zone, with the initially mature zone having a top at 2400m. The reflectance gradient at the 0.6% vitrinite reflectance horizon, is 0.23%/km.

Belfast No. 4

Three of the four core samples are silty sandstones with inertinite abundant in the upper two samples and rare in the lowest sample. The other sample is a fine-grained clastic with d.o.m. chiefly inertinite but <0.5% in total. Exinite is sparse to very rare and while vitrinite is present, the vitrinite populations are relatively poorly defined both morphologically and in terms of reflectance contrast with both exinite and massive inertinite. The dominance of inertinite in the d.o.m. implies a relatively poor hydrocarbon potential.

The reflectance data may indicate the reflectance gradient, but come from a relatively small depth interval. The reflectance and fluorescence data suggest that the well terminated before reaching the zone of oil maturity.

Argonaut No. 1

U.Woll. No.	Depth (m)	R̄%	Range	N	Exinite fluorescence (remarks)
9778	1305	<0.60	-	-	Sporinite rare, orange. (Massive inertinite abundant in silty pyritic ss. Probably no vitrinite present.)
9779	1807	?0.38	0.26-0.44	5	Sporinite and cutinite sparse to common, orange. (Interbedded ss. and carb. shale with abundant semifusinite, vitrinite population not well-defined.)
9780	2734	0.59	0.48-0.74	12	Liptodetrinite rare, yellow to orange, some ?suberinite, reddish-brown. (Clay-rich poorly sorted ss. with abundant I and rare V, shell fragments present.)
9781	3448	0.69	0.62-0.75	3	Rare, bright yellow ?dinoflagellates, orange liptodetrinite. (Sandy fine grained siltstone, d.o.m. common, chiefly fine-grained inertinite with a very poorly defined vitrinite population. Patches of bright yellow mineral fluorescence.)
9782	3554	0.78	0.55-0.92	17	Sparse to common cutinite, bright yellow, and liptodetrinite yellow orange. (Clay-rich ss. with a well-defined population of vitrinite, inertinite dominant over vitrinite.)
			Belfast No. 4		
9815	1152	0.23	0.20-0.27	5	Sparse greenish yellow sporinite. (Sandy siltst. with abundant I and rare V.)
9816	1418	0.40	0.35-0.44	2	Exinite rare, mainly liptodetrinite, but an entire dinoflagellate found, bright yellow to orange. (Siltst. with abundant I, and very rare V. Shell fragments and pyrite present.)
9817	1628	0.44	0.34-0.48	8	Rare to sparse liptodetrinite of dinoflagellate origin, brilliant greenish, yellow. (Pale clay-size clastic, with d.o.m. <0.5%and vitrinite very rare.)
9818	1679	-		-	Very rare sporinite and liptodetrinite, orange to dull orange. (Ss. with some lithic grains, d.o.m. rare chiefly I.)

Burrungule No. 1

The samples are all cuttings samples and with the exception of that from 1677m are dominated by sandstone. All samples contain either massive vitrinite, or, vitrinite occurring in carbonaceous siltstones and shales. Most contain both forms of vitrinite. Inertinite is the dominant maceral in the carbonaceous siltstone and shales. The coals are vitrinite rich but contain significant inertinite and exinite is abundant - 5 to 15%. Exinite is sparse to rare or absent in the clastic lithologies. "Fry-panning" was noted in some samples.

Adequate vitrinite populations were obtained for four of the samples, but that in the two samples below 2000m is probably a cavings or recirculated cuttings population. The reflectances in the upper part of the section (1441m to 1930m) are unusually high for this depth in the Otway Basin sequence. The top of the zone of initial maturity probably lies between 1200m and 1700m. The doubtful nature of the data below 2000m makes it impossible to calculate a reflectance gradient.

Burrungule No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9783	1441	0.55	0.45-0.65	14	Very rare liptodetrinite, orange. (Some carb. siltst. with sparse I and V, rare huminite grains.)
9784	1488	0.52	0.48-0.54	3	Very rare sporinite, orange. (Dominantly sandstone, some siltst., rare vitrinite. Some carbonate grains which fluoresce orange.)
9785	1677	0.50	0.41-0.58	25	Abundant, cutinite, sporinite and resinite, yellow to orange. (Coal 20%, vitrinite rich but I up to 40% and E 5-10%. Siltstone with common sporinite, orange, and resin, bright orange. Orange fluorescence prominent in carbonates.)
9786	1930	0.62	0.51-0.76	3	Rare sporinite, orange, in carb. shales and siltst. (D.o.m. largely confined to carb. shales and siltstones, sparse and dominantly I, V is very rare.)
9787	2151	0.55	0.47-0.64	13	Sparse liptodetrinite, ?sporinite, ?resin, yellow to orange in the sparse carb. shale. (Very rare massive vitrinite, some of it "frypanned". Some orange fluorescing fusiform carbonate crystals.
9788	2397	0.58	0.49-0.78	13	Similar to 9787 but no massive vitrinite present.

Caroline No. 1

The suite of samples, overall contains abundant inertinite sparse exinite and some vitrinite. The vitrinite is typically partly replaced by pyrite. A distinctive vitrinite population is not present in the sample from 1250m, but unequivocal vitrinite can be found in all the other samples. Some of the vitrinite in the deepest sample (3369m) cuts across the bedding and is probably derived from root tissue. Minor rim fluorescence is present on some quartz grains as shallow as 1829m and mineral fluorescence is prominent in the sample from 3068m.

The well was terminated close to the base of the main oil generation zone with the reflectance gradient about 0.20%/km down to 3100m but rising sharply below that depth.

Casterton No. 1.

The one sample from this well is a fine-grained claystome with rare d.o.m. other than inertinite which is common. The section appears to be immature but may have some source potential if it occurs at higher levels of maturity.

Caroline No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9773	1250	0.24	-	1	Cutinite, rare, orange, resinite, sparse, greenish yellow to brown. (Silty claystone with abundant I, most of it in the reflectance range 0.70% to 0.90%)
9774	1829	0.53	0.48-0.57	5	Liptodetrinite rare, orange. (Clay-rich ss, rare shell fragments, elongate vitrinite layers, with rim fluorescence on some quartz grains.
9775	2425	0.60	0.45-0.73	11	Sparse to common sporinite and liptodetrinite, orange, rare bright green fluorinite. (Claystone and clay rich ss, abundant vitrinite, typically pyritized, I>V>E.)
9776	3068	0.69	0.59-0.74	3	Sparse sporinite, cutinite and resinite, orange to yellow orange. (Siltstone with abundant mineral fluorescence, rare V, abundant I.)
9777	3369	0.97	0.56-1.17	13	Rare sporinite, orange. (Pale fine-grained sltst. with rare but extensive vitrinite layers, one,perpendicular to bedding, probably representing a root.)

Casterton No. 2

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9828	1438	?0.46	-	?2	Liptodetrinite, sporinite and cutinite common, bright yelllow to orange, dominantly orange. (Fine-grained pale claystone, with shell fragments, d.o.m. rare apart from exinite.)

Fergusons Hill No. 1

The samples are silty sandstones and siltstones, with common to abundant d.o.m., chiefly inertinite, with a significant amount of vitrinite present in the sample from 743m. Fluorescing exinite is common in the sample from 2237m, sparse in that from 743m, absent from the deepest sample, and rare in the other samples. With the exception of the sample from 743m, most of the humic material shows evidence of reworking. The absence of fluorescing exinite from the sample from 3484m is believed to be due to rank rather than type effects. Most samples contain pyrite.

The upper part of the section is characterized by low maturity and a low vitrinite reflectance gradient. The 0.5% vitrinite level is reached at about 1000m, and the reflectance gradient at the 0.6% reflectance level is low at about 0.1%/km. Below 2300m, a sharp inflexion must occur in the vitrinite reflectance profile, on the evidence provided by the data from the deepest sample. The vitrinite population in this sample (3484m), is poorly defined, and the large range of values, suggests that the mean may be accurate only to ±0.15%. The absence of fluorescing exinite does, however, confirm that the sample is of high maturity. The presence of ?coke structures in this sample implies that localized contact metamorphism has been a factor near T.D.

Flaxmans No. 1

The dispersed organic matter is dominantly inertinite, but exinite is abundant in the sample from 2397m. Organic matter is rare in the sample from 2709m and the vitrinite reflectance for the sample from 3513m is sufficiently high for any exinite in this sample to have lost the property of autofluorescence.

The vitrinite populations in the samples were poorly defined and the data quality is not as good as for some other wells. The reflectances agree with the exinite fluorescence colours and are thought to be an adequate indication of the maturity of the section. The top of the zone of initial oil maturity appears to be relatively shallow at between 1500m and 2000m. The zone of prolific oil generation lies from 2400m to about 3000m and one of the samples within this zone contains abundant exinite. The lowest sample is close to the oil deadline, and within the zone dominated by wet gas. The reflectance gradient is relatively low down to below 2709m but increases rapidly towards T.D., with the main inflexion probably being close to 3200m.

Fergusons Hill No.1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9836	471	0.30		1	Rare sporinite and cutinite, yellow to orange. (Silty ss., d.o.m. common chiefly I, takes a poor polish.)
9837	478	0.43	0.38-0.46	6	As for 9836.
9838	743	0.49	0.44-0.58	19	Sparse cutinite, sporinite and liptodetrinite, orange yellow to yellow. (Siltstone and shaly coal, abundant vitrinite, I rare. Framboidal pyrite abundant.)
9839	947	-	-	-	Rare yellow to orange sporinite. (Siltstone with sparse inertinite and no vitrinite.)
9840	2237	0.65	0.47-0.77	15	Exinite common, sporinite and cutinite yellow to dull orange, dinoflagellates and liptodetrinite greenish yellow to dull orange. (Siltstone with finely comminuted inertinite, common and vitrinite, rare. Pyrite present.)
9841	3484	1.57	1.20-2.02	14	No exinite fluorescence. (Coarse siltstone, common d.o.m. Vitrinite population poorly defined. Some ?coke mosaic present on one edge of sample pyrite present.)

Flaxmans No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9800	1519	0.50	0.39-0.60	4	Sparse exinite, sporinite, cutinite, resinite, bright yellow to orange. (Dirty ss. with common I but V is rare.)
9801	1945	0.42	0.32-0.51	2	Very rare dull orange liptodetrinite. (Sandy to silty mudstone, pyritic. D.o.m. common, chiefly of small grain size and mainly I.)
9802	2397	0.65	0.54-0.80	7	Sporinite and liptodetrinite yellow to orange, abundant in carb. siltst., but rare in claystone and ss. (D.o.m. ranges from common to rare, chiefly I and E with rare vitrinite.)
9803	2709	0.70	0.68-0.71	2	Trace of liptodetrinite, orange. (Claystone, d.o.m. very rare.)
9804	3513	1.17	1.00-1.25	10	No fluorescing exinite. (Lithic ss. with rare d.o.m. interbedded with siltst. with common d.o.m., predominantly I, but some V. Patchy mineral fluorescence.)

Glenelg No. 1

All four core samples are silty sandstones with inertinite common to abundant. Exinite is sparse to rare and while vitrinite is present, the vitrinite populations are poorly defined both morphologically and in terms of reflectance contrast with both exinite and massive inertinite. Thus some of the low vaues could be exinite, suberinite or bitumen. Cutinite of reflectance 0.42% and suberinite of reflectance 0.56% are present in the sample from 2057m and these values overlap with some of the vitrinite values from a sample only 82m above. Equally some of the higher reflectance material recorded as vitrinite could be massive inertinite. The fluorescence characteristics of the exinite are more in accord with the higher $\overline{R}_o$max values than with the lower values. The dominance of inertinite in the d.o.m. implies a relatively poor hydrocarbon potential. The presence of <u>Botryococcus</u>-related alginite, is unusual for the organic matter in the Otway Basin sediments. The amount found is too small to be significant in itself, but does indicate the possibility of a lateral passage into a facies with more, oil-prone organic matter.

The reflectance data are not sufficiently constrained to indicate a reflectance gradient, but suggest that the well did enter the oil mature zone. The exinite fluorescence colours from the deepest sample imply that it is from the more mature part of the main oil generation zone.

Heywood No.10

The three samples cover a relatively narrow depth range. The uppermost sample contains abundant d.o.m. A well-defined population of vitrinite is present, together with significant amounts of exinite. The lower samples have a much lower content of d.o.m., little exinite and little or, in the case of the deepest sample, possibly no vitrinite. The vitrinite reflectance from 1356m indicates that this part of the section is immature, and, unless the reflectance gradient at this location is unusually high, the section down to 1640m is probably immature also.

Glenelg No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9811	1582	0.69	0.55-0.80	8	Rare sporinite and liptodetrinite, medium orange, cutinite yellow. (Ss. with silty layers, rich in I and with some poorly defined vitrinite. Shell fragments present.)
9812	1762	0.50	0.43-0.64	7	Sporinite and liptodetrinite rare, yellow to dull orange. (Silty ss. with abundant sand and silt sized SF and ID. Rare thin layers of vitrinite.)
9813	1975	0.48	0.44-0.50	3	Similar to 9812 but pyrite more abundant.
9814	2057	0.77	0.62-0.91	18	Sporinite sparse, orange to dull orange. Two colonies of Botryococcus-type alginite present, brilliant yellow fluorescence. (Silty ss. with common I and sparse vitrinite. Shell fragments and pyrite present.)

Heywood No. 10

9805	1356	0.41	0.29-0.54	25	Abundant cutinite, sporinite, resinite, bright yellow to orange. (Carb. shale with abundant thin layers of vitrinite, exinite, and inertinite, V>E>I. Distinct positive alteration of exinite and of clay groundmass on prolonged irradiation.)
9806	1467	0.56	-	1	Sparse sporinite and cutinite, bright yellow to orange. Rare dinoflagellates present with dull orange fluorescence. (Sandy carb. siltst. with abundant I and very rare vitrinite.)
9807	1640	?0.60	0.56-0.64	?2	Sparse liptodetrinite, sporinite, cutinite and resinite, orange to yellow. (Siltst. with abundant I, identification of vitrinite doubtful.)

Kalangadoo No. 1

Seven core samples were available covering the interval from 611m to 2249m. Most of the lithologies are sandy or silty. Exinite is abundant in a shaly coal from 1455m and common in a shale from 1455m and in silty units from 1719m and 2023m. The sample from 2249m contains no fluorescing exinite. A small amount of inertodetrinite is identifiable in the sample from 2249m, but the majority of the organic matter in this sample consists of unidentifiable, fine, anastomosing laminae. The abundant sporinite in the shaly coal at 1455m has unusually subdued fluorescence intensity, and equally has unusually marked positive alteration characteristics.

The section down to 1719m is clearly immature. Vitrinite in the sample from 2023m is neither abundant, nor well-defined. If the reflectances from this depth are representative, a marked jump in maturity occurs between 1719m and 2023m. The top of the zone of initial maturity is probably close to 1800m. The reason for the absence of fluorescing exinite in the sample from 2249m is not clear, but a continued high reflectance gradient would be implied if the cause is a high level of maturity.

Kalangadoo No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9793	611	0.33	-	1	Exinite rare, sporinite, cutinite, fluorinite, bright greenish yellow to orange. (Silty ss., d.o.m. common chiefly I, V is rare.)
9794	764	0.35	0.26-0.45	12	Sparse sporinite and liptodetrinite and ?dinoflagellates ,greenish yellow to orange. (Silty ss., d.o.m. common chiefly I, V is sparse.)
9795	895	0.36	0.20-0.45	7	Exinite rare to sparse, cutinite sporinite and liptodetrinite, yellow to orange and dull orange. (Sandy siltst. with abundant organic matter chiefly I, large masses of pyrite are present.)
9796	1455	0.42	0.34-0.46	7	Sporinite very abundant in shaly coal, dull orange but showing strong positive alteration to bright yellow. Brilliant greenish yellow to dull orange brown resin bodies. Cutinite dull orange to brilliant yellow. (Shaly coal and carb. shale both with abundant exinite and I but rare V. D.o.m. approx 20% overall and approx 10%E.)
9797	1719	0.45	0.39-0.52	18	Exinite common to abundant, sporinite cutinite, and liptodetrinite, typicaly bright yellow to orange but some very dull orange. (Silty carb. shale with d.o.m. common. V abundant but in thin layers, some probably being in situ roots.)
9798	2023	0.75	0.73-0.77	4	Common sporinite and shreds of cutinite, bright yellow to orange, rare resin, orange. (Sand siltst., d.o.m. chiefly E with thin layers of I and V, shell fragments present.)
9799	2249			-	No fluorescing exinite present. (Silst. with numerous fine laminae probably related to vitrinite but too thin to take a polish, pyritic.)

Lake Bonney No. 1

The samples (three core and one cuttings sample) are silty sandstones or sandstones. The d.o.m. is mainly inertinite but exinite is common or sparse to common in the lower two samples. Vitrinite is not abundant in any of the samples.

The depth range over which samples were available is small, and the vitrinite reflectances show no significant trend with depth. The reflectance data indicate that the top of the zone of initial maturity probably lies between 2000m and 2500m, and that the well was terminated before entering the zone of prolific oil generation.

Mount Salt No. 1

The five samples are all fine silty sandstones or sandy siltstones with d.o.m. abundant except for the sample from 2567m. Inertinite is the dominant component of the d.o.m. with exinite sparse except in the sample from 2567m where it is rare. Vitrinite is rare to sparse in all samples. The exinite consists of liptodetrinite, sporinite, cutinite and resinite with minor fluorinite being present in the sample from 3060m. Exinite fluorescence colours range from dominant yellow at 731m to dominant orange at 3003, and 3060m. Some of the cutinite which fluoresced a dull orange initially showed positive alteration to bright orange after 20 minutes irradiation. The sample from 1382m contains a thin layer of shaly coal. This is inertinite rich and contains only a small percentage of exinite (<2%).

The vitrinite reflectance shows a marked increase from about 0.43% at 1382m to about 0.65 to 0.75% at depths greater than 3000m. The quality of the data from 2419m and 2567m is poor so that precision is lacking for the middle part of the reflectance profile. The top of the zone of initial maturity probably lies at about 2300m.

Lake Bonney No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9789	2375	0.63	0.48-0.81	14	Rare cutinite and sporinite yellow to orange. (Ss., silty, with abundant SF and rare V, shell fragments present.)
9790	2563	0.53	0.45-0.60	7	Resinite yellow to orange, cutinite dull orange. (Sandy siltstone, rare massive vitrinite and I and E rich coal. Fluorescing carbonate common.)
9791	2718	0.61	0.54-0.70	10	Liptodetrinite common, sporinite derived, yellow to orange. (Sandy siltst. with abundant I and rare V. Carbonate with rare I and E.)
9792	2908	0.55	0.48-0.68	20	Sparse to common sporinite, cutinite, liptodetrinite and ?dinoflagellates, bright yellow to orange. (Siltst. with rare pyrite, d.o.m. sparse chiefly I some V.)

Mount Salt No.1

9819	1382	0.45	0.33-0.60	17	Sporinite, cutinite, brilliant yellow orange, sparse. (Ss.,siltst., and shaly coal, the ss. being extensively pyritized. The d.o.m and the shaly coal are both dominated by inertinite, V is common and exinite sparse to rare in all lithologies.)
9820	2419	0.46	0.30-0.60	10	Sparse to common liptodetrinite, sporinite and cutinite, yellow to orange. (Siltst. with abundant d.o.m., dominated by I. Pyrite and shell fragments present.)
9821	2567	0.47	0.39-0.67	8	Rare liptodetrinite, orange. (Pyritic silty ss., with shell fragments and sparse d.o.m., chiefly I.)
9822	3003	0.62	0.50-0.80	22	Sparse cutinite, sporinite and liptodetrinite, greenish yellow to orange. Some orange resinite present. (Pyritic coarse siltstone with shell fragments and abundant d.o.m., but V is sparse. I>>V>E. Cutinite shows strong positive alteration.)
9823	3060	0.74	0.57-0.83	14	As for 9822 but bright green fluorinite is also present in trace amounts.

Mussel No. 1

Both samples contain abundant d.o.m. and abundant exinite with a number of macerals of higher-plant origin being present. The coal from 2236m is especially rich in exinite with fluorinite being spectacularly abundant. A high liquid potential must be inferred for the Waarre Sandstone at this location.

The vertical separation is too small to permit construction of an accurate reflectance – depth profile, but the of the oil mature zone probably lies at about 1900m, and the reflectance gradient implied by the data at the 0.6% vitrinite reflectance level is 0.28%/km.

Nautilus No. 1.

The samples are evidently all marine since they contain dinoflagellates or calcareous nannofossils, or both. D.o.m. ranges from sparse to very rare. Exinite is common only in the sample from 2009m and is probably absent in the limestone from 1584m.

The vitrinite reflectance data are relatively poor in quality but are consistent with the exinite fluorescence colours in indicating a low level of maturity in the section from 1584m to T.D.

Mussel No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9834	2099	0.56	0.45-0.68	20	Common cutinite, fluorinite, sporinite and liptodetrinite, brilliant green to dull orange. (Silty shale with abundant d.o.m., I>V>E. Pyrite present.)
9835	2236	0.59	0.53-0.66	22	Abundant exinite, R/Fl>Ld>C>Sp. Fluorinite typically brilliant green, other exinite macerals yellow to dull orange. (Coal, shaly, vitrinite rich with approx. 10% E and rare I. Pyrite present, negative alteration noted in fluorinite, and no alteration for the other exinite macerals.)

Nautilus no. 1

9830	1263	-		-	Sparse dinoflagellates greenish yellow. (Pyritic silty claystone, with abundant shell fragments and foraminifers abundant. D.o.m. very rare apart from exinite.)
9831	1584	?0.36		?1	Exinite probably absent. (Fine micritic carbonate with abundant nannofossils some of which fluoresce very strongly. D.o.m. extremely rare.)
9832	1860	0.53	0.40-0.63	10	Sparse liptodetrinite greenish yellow to orange. (Claystone with sparse d.o.m., chiefly I, common pyrite and abundant nannofossils.)
9833	2009	0.52	0.43-0.60	3	Common sporinite and liptodetrinite bright greenish yellow to orange, mode at yellow. (Claystone with sparse d.o.m., chiefly I, abundant framboidal pyrite, commonly associated with exinite, and some calcareous nannofossils.)

North Eumeralla No. 1

The source potential of the sequence does not appear to be high (Plate 23) but some lithologies containing significant amounts of exinite are present at 2130m and 2689m.

The vitrinite reflectance is close to 0.7% near the base of the Cretaceous part of the succession. There appears to be little if any break in the coalification curve corresponding with the unconformities noted in the logs.

North Eumeralla No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range %	N	Exinite fluorescence (remarks)
9761	915 Ctgs	0.42	0.33-0.45	5	Sporinite, yellow, very rare. Possible wurtzilite grain. (Rare huminite grains.)
9762	1010 Ctgs	0.43	0.33-0.48	26	Sporinite, yellow, rare, sparse orange resinite. (Sample consists almost entirely of textoulminite and eu-ulminite.)
9763	1496	0.43	0.32-0.55	25	Sporinite rare to sparse, yellow to orange, grain of greenish yellow fluorinite noted. (Rare carb. shale, inertinite the majority of the d.o.m., very rare grains of coals, exinite rich.)
9764	1923	0.56	0.48-0.72	22	Sporinite and cutinite sparse, yellow orange to orange, rare yellow ?dinoflagellates. (Rare coal, shaly coal and carb shale, organic matter rare overall in sample.)
9765	2130	0.58	0.47-0.71	20	Exinite sparse to common, sporinite bright yellow to dull orange. (Vitrinite abundant in shaly coal and in carbonaceous shale.)
9766	2669	0.68	0.60-0.80	17	Sporinite bright yellow to orange rare overall but common in coal grains. Exsudatinite, orange, noted in vitrinite. (Coal rare, low in mineral matter.)

Pecten No. 1 and No. 1A

The upper three samples contain sparse exinite dominantly of higher plant origin. Coaly material similar to that in these upper horizons is present in the lower two horizons and is believed to represent cavings or recirculated cuttings. A much less abundant, higher reflectance population is considered to be more likely to be representative of the maturity level in the lower part of the section. The apparent abundance of cavings in the lower samples precludes any conclusions concerning exinite abundance in the Otway Group.

Vitrinite reflectance rises from about 0.4% near 1300m to above 0.8% near T.D. The reflectance gradient at 0.75% of 0.30%/km is moderate to high for the Cretaceous to Tertiary basins of Southeastern Australia.

Port Campbell No. 2

The samples are silty or sandy shales. D.o.m. is abundant and is dominated by inertinite, except for the sample from 2404m, in which it is sparse, consisting of inertinite, rare liptodetrinite and no vitrinite. Vitrinite populations are well defined in some of the samples, although reworking is a significant factor in the characteristics of the d.o.m. in most, if not all, of the samples. Pyrite and shell fragments are abundant.

The zone of initial maturity is reached at about 1900m, and a relatively high vitrinite reflectance gradient of about 0.45%/km is present at the 0.6% vitrinite reflectance level. The presence of fluorescing liptodetrinite in the deepest sample, implies that the vitrinite reflectance at this horizon would be less than 1.00%. Some unusual fluorinite or oil-cut bitumen was noted in the sample from 2343m.

Pecten No 1 and No 1A

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9756	1339	0.39	0.28-0.48	16	Exinite sparse, bright yellow to orange sporinite. (D.o.m. chiefly inertinite.)
9757	1665	0.45	0.36-0.60	14	Sporinite sparse yellow to dull orange. (D.o.m. chiefly inertinite.)
9758	1808	0.45	0.40-0.56	5	Exinite rare to sparse, sporinite and phytoplankton greenish yellow to orange. (D.o.m. approx 5%, chiefly inertinite.)
9759	2398	0.84	0.76-0.88	3	One grain only, contains cutinite with very dull red-brown fluorescence and $R_E$max = 0.20%.
		0.55	0.43-0.64	21	Dominant population but probably cavings, exinite sparse yellow orange to orange.
9760	2842	0.81	0.65-1.00	8	Some fluorescing resins associated with vitrinite in the range R 0.65 to 1.00%. (A cavings population with abundant exinite and R_V = 0.52% is present. Suberinite reflectance of 0.4% noted.)

Port Campbell No. 2

9842	1902	0.51	0.40-0.56	6	Rare dull orange sporinite and dinoflagellates, orange to dull orange. (Siltstone with abundant I, and a poorly defined population of vitrinite, rare. Shell fragments and pyrite present.)
9843	2162	0.64	0.60-0.71	6	Dinoflagellates sparse, greenish yellow, sporinite, exinite, rare, orange to dull orange. (Silty shales, d.o.m. similar to 9844.)
9845	2343	0.83	0.65-1.00	15	Common cutinite, sporinite bright yellow to orange. Fluorinite or oil cut bitumen present filling cell cavities in wood and filling pore spaces in sediment, bright orange. (Silty shale, abundant E, some large pieces of reworked coal/peat, vitrinite population poorly defined, but V may be relatively common. Pyrite abundant, shell fragments present.)
9843	2404	-	-	-	Rare liptodetrinite chiefly orange but some dull orange. Rare green to orange fluorescence from ?dead-oil. (Mudstone with sand-size quartz and ?faecal pellets, sparse I, no V.)

Portland No. 1

The three samples cover a relatively short interval and the existence of vitrinite in the upper and lower samples is doubtful. The reflectances obtained for the sample from 1611m are unusually high for this depth in the Otway Basin. The value of 1.41% from 1715m probably relates to inertinite or reworked vitrinite. If it does relate to vitrinite, it is probable that contact metamorphism from igneous activity has occurred and the presence of chalcopyrite may be significant. The samples have low source-potential in terms of the abundance and type of organic matter and the level of maturation is not well defined.

Pretty Hill No. 1.

Dispersed organic matter is abundant in the upper two samples, but is sparse in the other samples. Exinite is sparse in all samples and the d.o.m. is typically dominated by inertinite.

The vitrinite reflectance data are of variable quality with a precise value being obtained for a well defined vitrinite population in the sample from 1023m. The value of 0.78% at 1809m is significantly higher than that at 1023m and is relatively poorly controlled but is consistent with the exinite fluorescence and the presence of rim fluorescence on quartz grains. The maturation data suggest that the top of the oil mature zone lies at about 1400m and that T.D. was probably in, or close to the zone of peak oil generation. The reflectance gradient, at the 0.6% vitrinite reflectance level, is high at about 0.6%/km.

Portland No. 3

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9808	1419	?0.63	0.59-0.67	2	Rare liptodetrinite, yellow to orange. (Friable ss. with d.o.m. rare interbedded with siltst. with common d.o.m., chiefly I. Identification of vitrinite is doubtful.)
9809	1611	0.78	0.64-0.95	16	Rare orange to dull orange sporinite, and orange cutinite. (Pyritic ss. Vitrinite is not well defined, but reflectances are consistent and cell structure is generally lacking.)
9810	1715	?1.40	-	1	No fluorescing exinite. (Sample consists of white pyritic ss. and ?bitumen impregnated sandstone. The ?bitumen may have very weak fluorescence but is thought to be one of the more mature pyrobitumens such as impsonite. Chalcopyrite and sphalerite are present in the white ss.)

Pretty Hill No. 1

9824	731	0.34	0.28-0.43	7	Sparse cutinite and sporinite, brilliant yellow to orange. (Friable fine silty ss. with abundant d.o.m., I>V>E.)
9825	1023	0.41	0.37-0.46	21	Sporinite and cutinite sparse, greenish yellow to orange. (Claystone with abundant vitrinite and inertinite. Vitrinite about 2% of rock, ulminite or textinite.)
9826	1167	0.45	0.41-0.55	3	Common sporinite and sparse cutinite, yellow to orange. (Silty claystone with sparse d.o.m. and common pyrite. I>E>V.)
9827	1418	0.52	0.50-0.54	2	Similar to 9826 but shell fragments present.
9828	1809	0.78	0.76-0.79	2	Liptodetrinite and cutinite sparse, yellow to orange. (Fine siltst. with rim fluorescence on some quartz grains.)

Rowans No. 1

The samples contained grains of massive vitrinite (Plate 30) which were rare except for the lowest sample. Exinite is not common, with the dominant maceral in the carbonaceous shales being inertinite. The appearance and texture of the vitrinite is similar in all specimens and the lower samples may represent cavings or recirculated cuttings. Thus, it is considered that the section below 1298m is marginally mature but no indication of reflectance gradient was provided by the samples.

Voluta No. 1

The suite of samples contains abundant inertinite and rare exinite with vitrinite being rare in most samples and being difficult to distinguish from low reflectance inertinite in all samples. This latter problem results in a relatively wide range of readings for most samples and some scatter from a smooth curve.

The well penetrated the full depth of the main oil generation zone within the Belfast Mudstone. Mineral fluorescence is a prominent feature of samples from the lower part of the sequence. The reflectance gradient at the 0.6% reflectance level is moderate to high at 0.32%/km.

Rowans - 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9752	1298	0.51	0.47-0.54	8	Exinite rare, brilliant yellow sporinite and cutinite, very rare ?dinoflagellates in carbonates. (Rare grains of vitrinite.)
9753	1550	0.50	0.50-0.51	3	Liptodetrinite rare to sparse, yellow to orange. (Carb. shales abundant but most of organic matter is inertinite. ?Bitumen present, fluoresces dull greenish-brown.)
9754	1623	0.49	0.42-0.54	8	Rare sporinite and liptodetrinite yellow to orange. (Rare vitrinite grains, in carb, shales inertinite is dominant maceral.)
9755	1756	0.49	0.42-0.57	28	Rare sporinite and liptodetrinite, yellow to orange, rare resinite. (Grains of vitrinite common.)

Voluta No. 1

U.Woll. No.	Depth (m)	$\bar{R}$%	Range	N	Exinite fluorescence (remarks)
9767	1414	?0.38	-	1	Rare sporinite yellow to orange. (Siltstones with abundant inertinite, vitrinite rare or absent.)
9768	1792	0.38	0.34-0.42	3	Sporinite sparse, bright yellow to orange. (Siltstones with abundant inertinite but other macerals rare.)
9769	2165	0.66	0.62-0.76	4	Sporinite and resinite, rare, yellow to orange. (Clay rich carb. silts., I abundant, mineral fluorescence rare.)
9770	2674	0.58	0.50-0.70	5	Sporinite and liptodetrinite, rare, yellow to orange. (Silty ss. with abundant I.)
9771	3037	0.72	0.60-0.84	2	Similar to 9770, but shelly fossils present.
9772	3653	0.95	0.74-1.20	17	Rare orange liptodetrinite. (Siltstone with prominent patchy bright orange mineral fl., small vitrinite phytoclasts, elongate to equidimensional.)

PLATES

The Plates have been printed from photomicrographs using 35 mm transparencies. All the photomicrographs were taken using oil immersion. Objectives having nominal magnifications of 32, 50 or 125 were used, but the use of a vario-orthomat camera gives a wide range of magnification, which is indicated by the field width in each Plate caption. Polarized light was not used for most of the photographs, and this reults in a loss of contrast in the photographs of carbonates but has little or no effect on the appearance of the organic matter. The photographs are oriented towards the exinite group of macerals, for which fluorescence mode is essential. The fluorescence mode illuminator gives a complex purple cast when used in reflected light mode. The reflected light photomicrographs were taken using this dichroic illuminator to ensure accurate registration of the fields for comparative purposes, and the purple cast removed by the use of a K460 (green) filter.

For some of the Plates, the depths do not correspond with those of the samples supplied for the present study. These have been taken from my existing file of photomicrographs of that well because they illustrate the feature better than any of the fields found in the present study.

PLATE CAPTIONS

KEY

V - Vitrinite
Tu - textoulminite
Dc - desmocollinite

E - exinite
C - cutinite
D - dinoflagellate
Exs- exsudatinite
Fl - fluorinite
LD - liptodetrinite
R - resinite
S - sporinite

I - inertinite
F - fusinite
ID - inertodetrinite
SF - semifusinite

B - bitumen

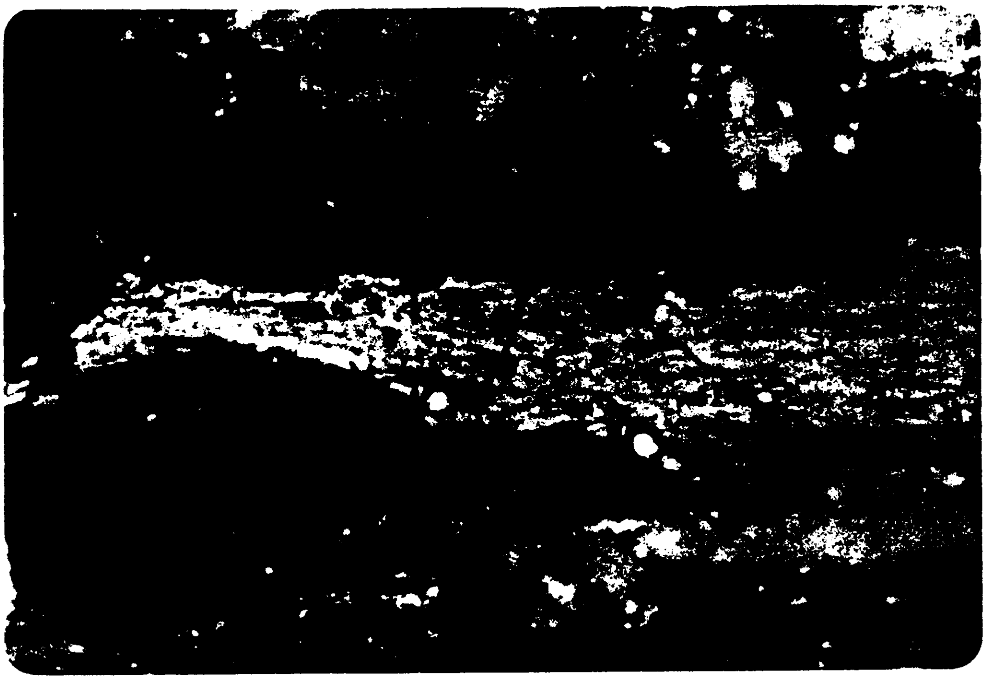
Ca - carbonate (most of the carbonates illustrated are dominated by calcite)
Q - quartz
Py - pyrite

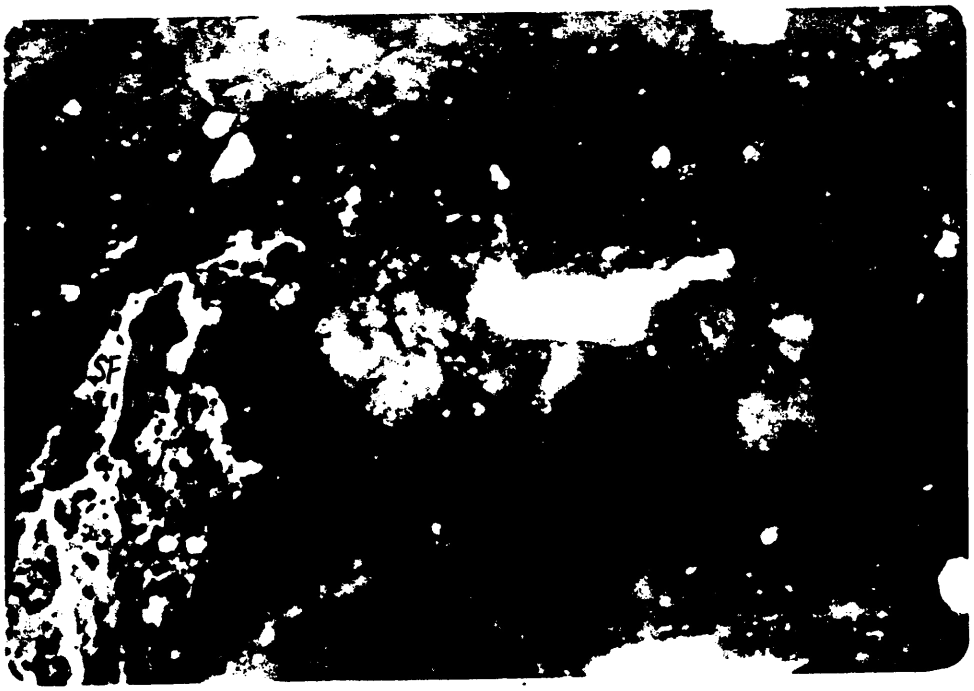
R.L. - reflected light mode
Fl. - fluorescence mode.

ARGONAUT

Plate 1. Massive semifusinite adjacent to a thin layer of vitrinite in a clay-rich sandstone. 2734m, $\bar{R}_o$max 0.59. R.L., field width 0.34mm.

Plate 2. Thin layers of vitrinite and a larger mass of semifusinite. 3554m, $\bar{R}_o$max 0.78%. R.L., field width 0.34mm.

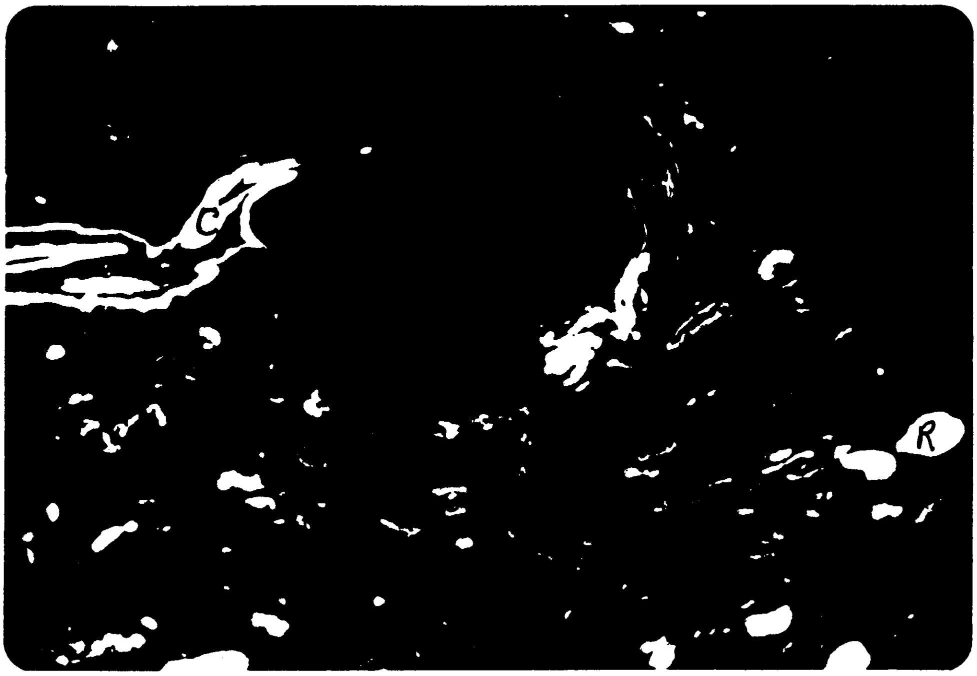



SF

BURRUNGULE

Plate 3. Exinite- and vitrinite-rich coal, containing exinite having a wide range of fluorescence intensity and colour. 1677m, $\bar{R}_o$max 0.50%. Fl., field width 0.53mm.

Plate 4. As for Plate 3 but in reflected light. The majority of the vitrinite in this field is desmocollinite and has a markedly lower reflectance as compared with the oval mass of telocollinite. Small amounts of inertinite and pyrite are also present.


C
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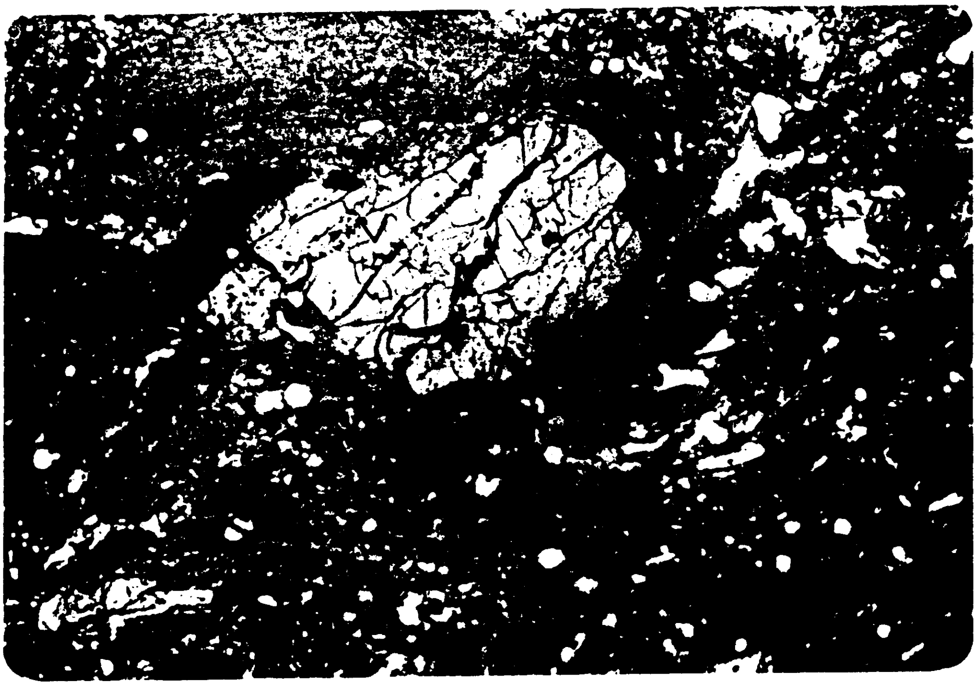
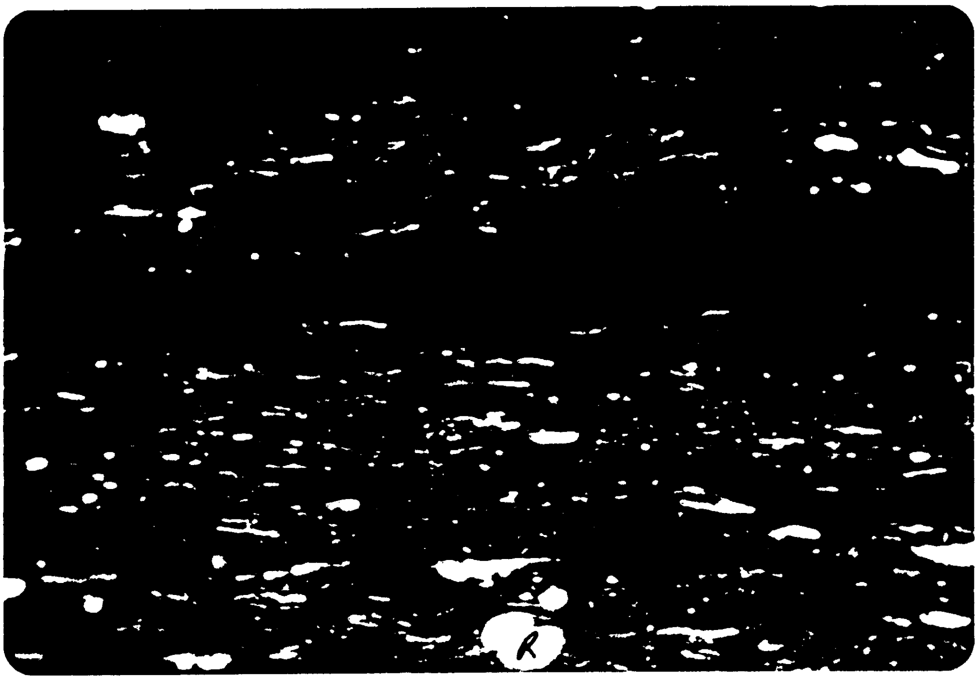


Plate 5. Exinite-rich coal. In addition to the strong yellow to orange sporinite and resinite fluorescence, this Plate shows weaker fluorescence from cutinite and very weak fluorescence from much of the desmocollinite. 1677m, $\bar{R}_o$max 0.50%. Fl.,field width 0.53mm.

Plate 6. As for Plate 5 but in reflected light. A range of inertinite macerals is present, together with pyrite.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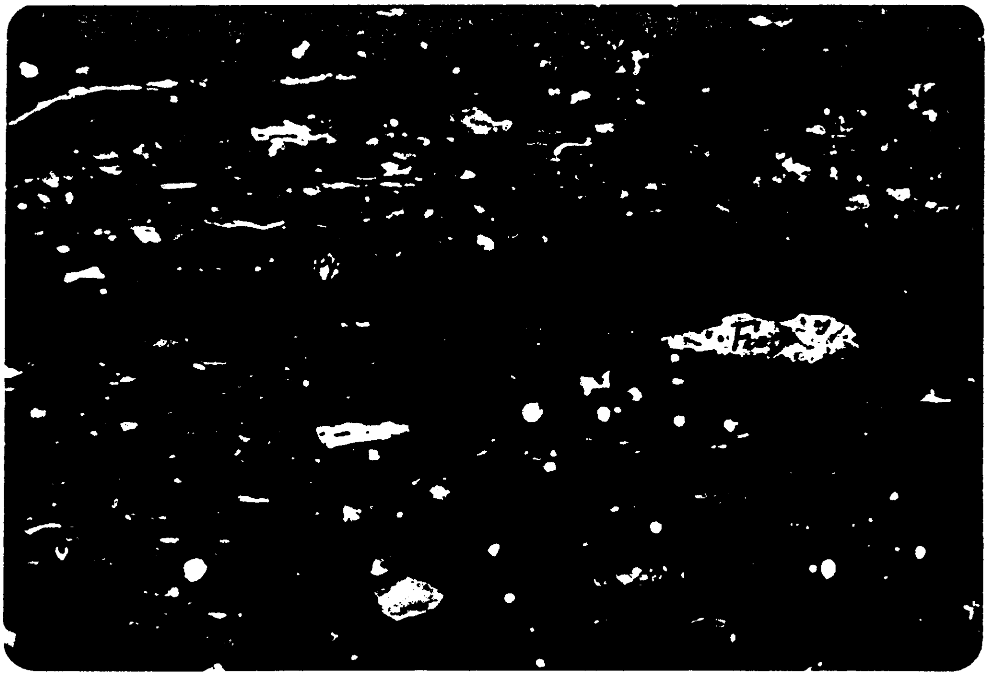

Fe

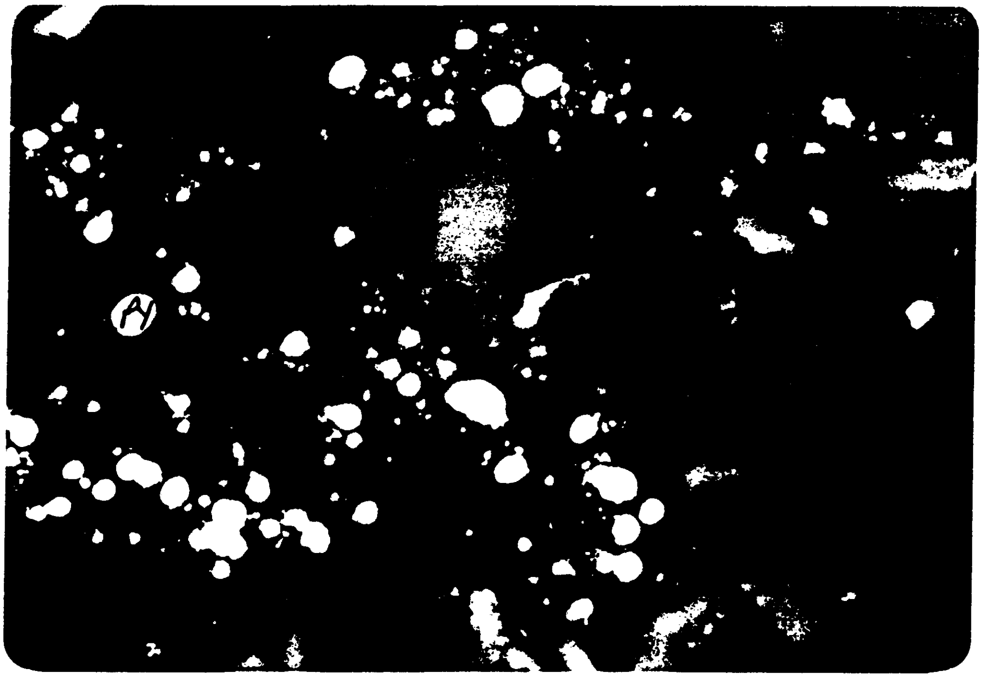
BURRUNGULE

Plate 7. Fluorescing carbonate mineral (probably calcite) occurring as a cement in a quartz sandstone. Minor pyrite is present and is easily distinguished from the "show through" of the primary beam (blue). 2377m, $\bar{R}_o$max 0.58%. Fl., field width 0.56mm.

CAROLINE

Plate 8. Vitrinite and semifusinite associated with pyrite. Note the relatively small contrast in texture between the two macerals. This lack of textural distinctiveness leads to difficulties in defining the upper reflectance limit of vitrinite. 2425m, $\bar{R}_o$max 0.60%. R.L., field width, 0.34mm.


ca

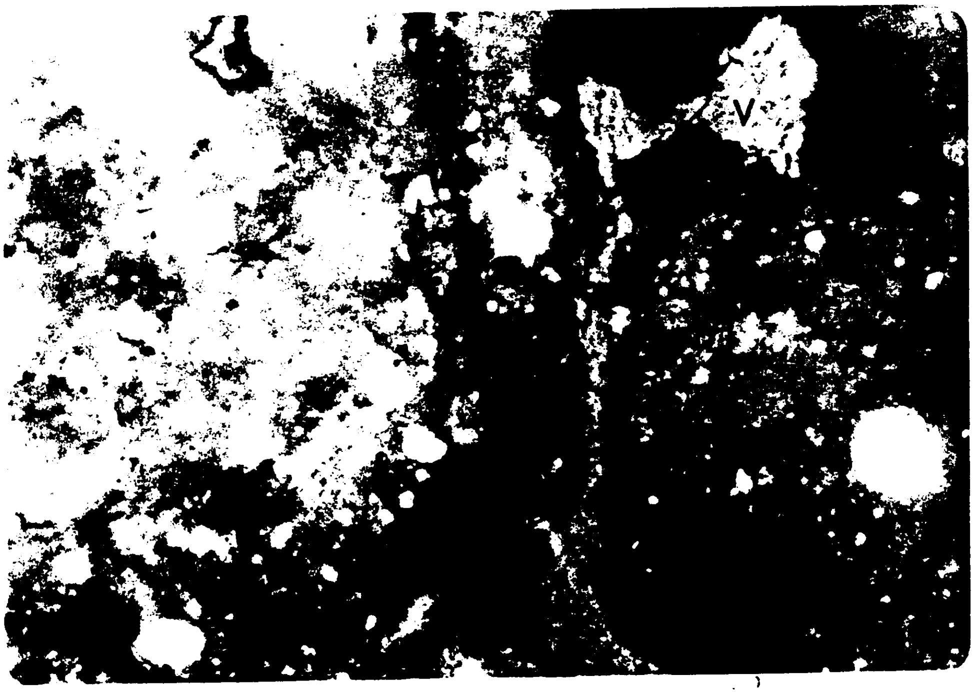

A

CAROLINE

Plate 9. Orange fluorescing sporinite seen in a section oblique to the plane of the bedding. 2425m, $\bar{R}_o$max 0.60%. Fl., field width 0.34mm.

Plate 10. Vitrinite phytoclast elongate perpendicular to the bedding. This occurrence is probably derived from a root, and is thus euautochthonous. The bedding of the siltstone is disturbed near the vitrinite, presumably as a result of plant-biotubation. The presence of this structure was of particular use in establishing the reflectance limits which should be used for the vitrinite in this sample. 3369m, $\bar{R}_o$max 0.97%. R.L., field width 0.34mm.


S


V

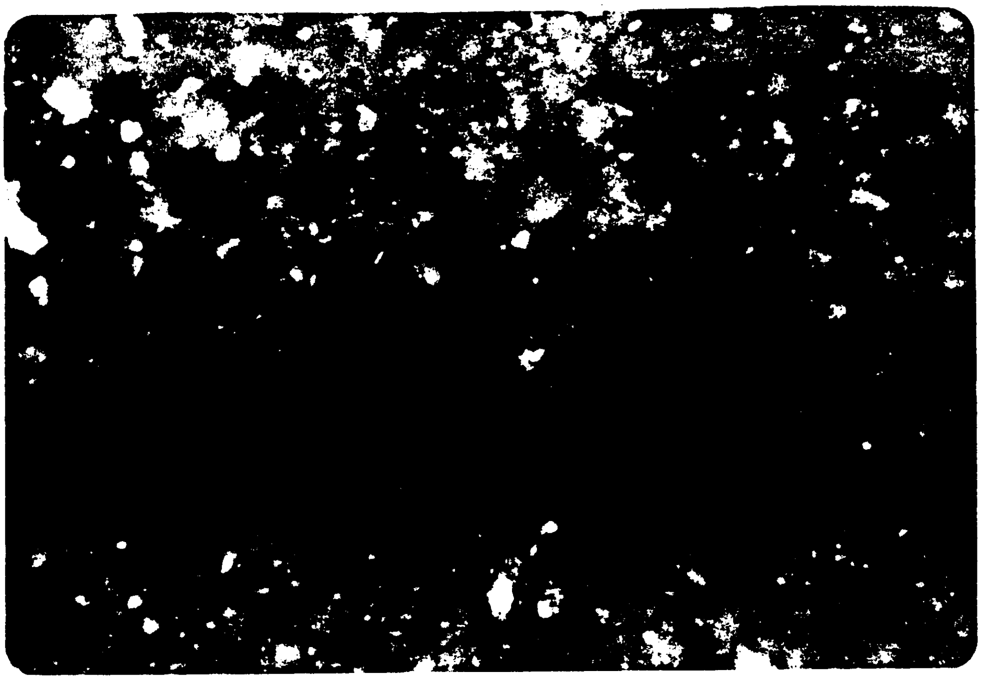
CAROLINE

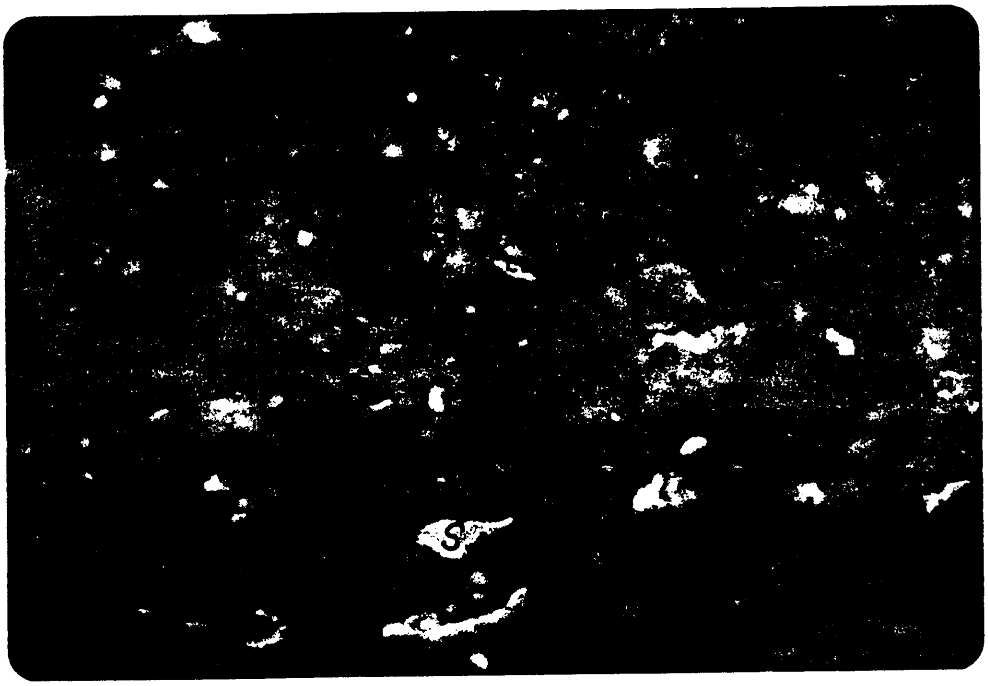
Plate 11. Layer of vitrinite parallel with bedding in a claystone. The size of the occurrence and the shape at the right hand side of the Plate, suggest that this occurrence is also autochthonous. 3369m, $\bar{R}_o$max 0.97%. R.L., field width 0.34mm.

FERGUSONS HILL

Plate 12. Sporinite and liptodetrinite occurring with inertodetrinite in a siltstone. This association is relatively common, but exinite is typically less abundant. 2237m, $\bar{R}_o$max 0.65%. Fl., field width 0.44mm.

Plate 13. As for Plate 12, but in reflected light.

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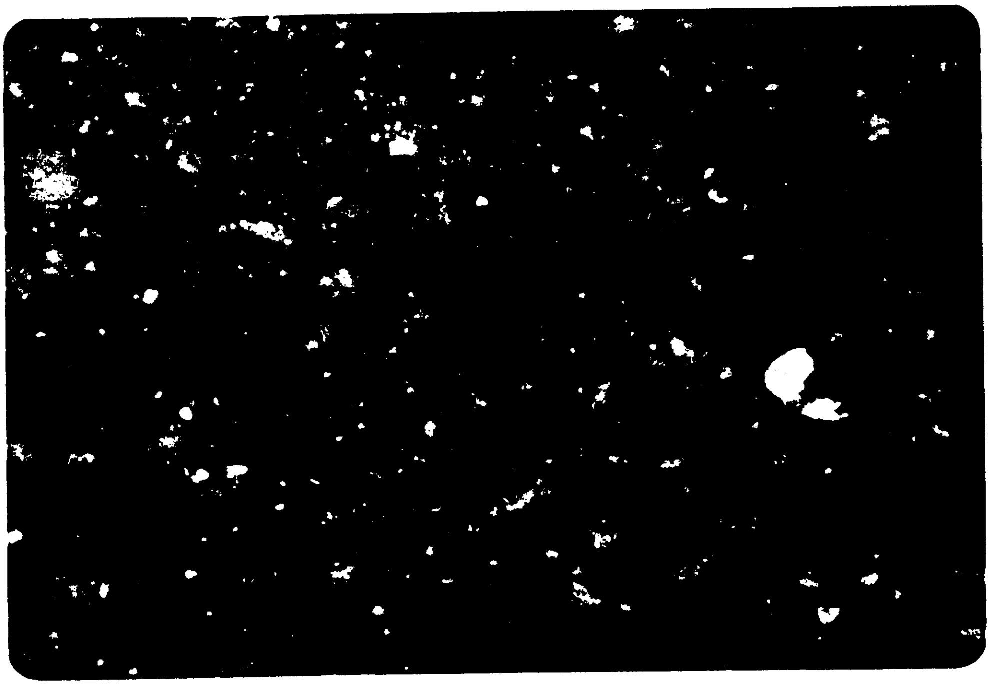

MUSSEL

Plate 14. Fluorinite occurring in the lumens of semifusinite, cutinite and a small vein of exsudatinite in a layer of duroclarite. 2286m, $\bar{R}_o$max 0.61%. Fl., field width 0.34mm.

Plate 15. As for Plate 14, but in reflected light. The cell structure of the semifusinite is more clearly seen in this mode. The occurrences of pyrite are partially recrystallized framboidal agglomerates.


R
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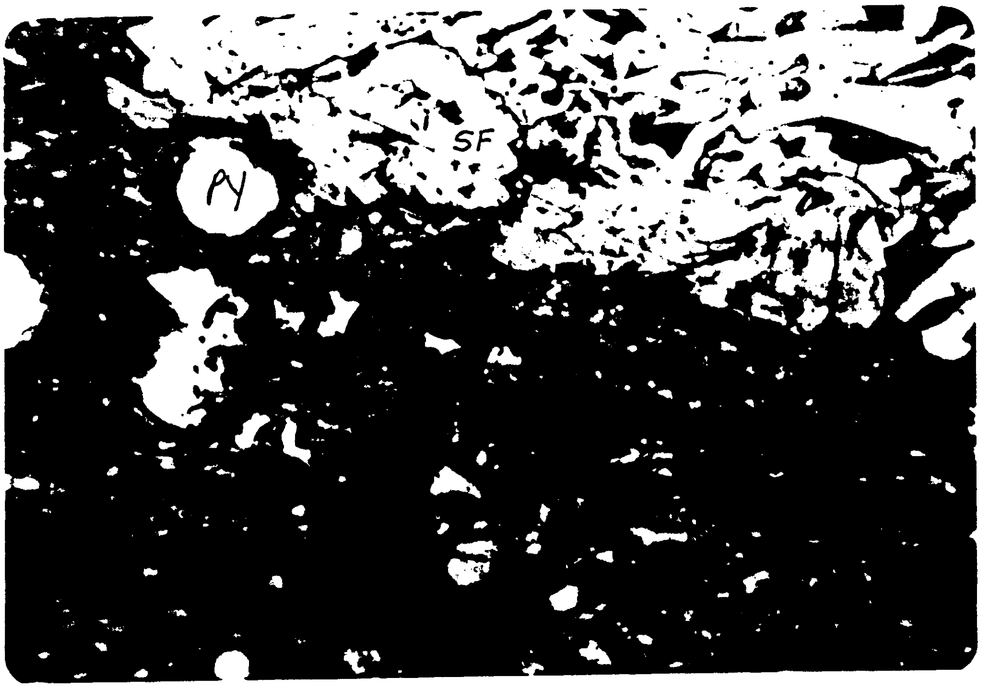
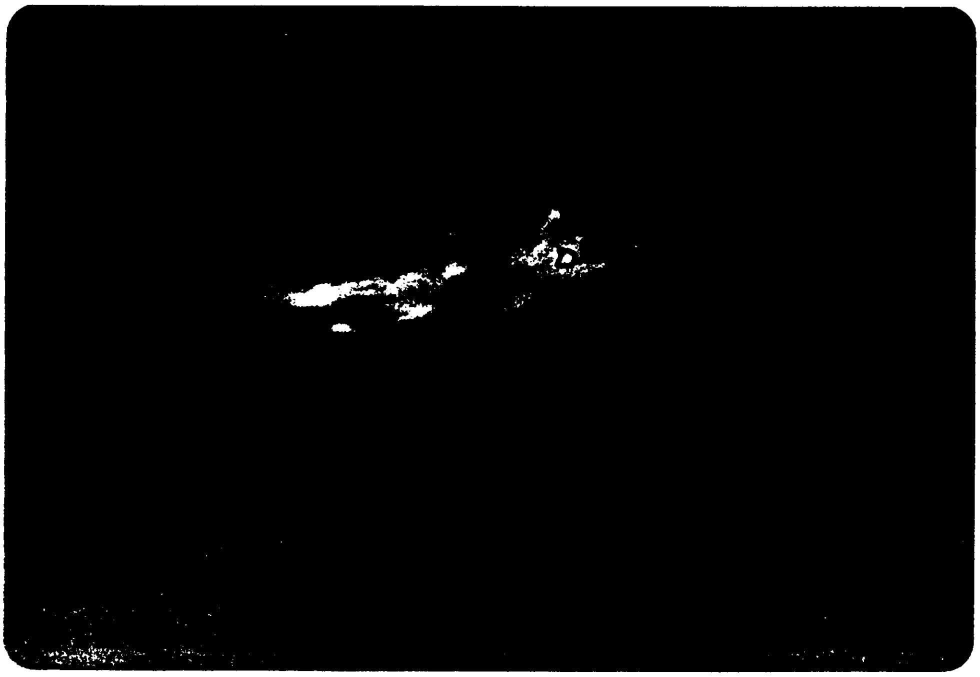
S
Exs

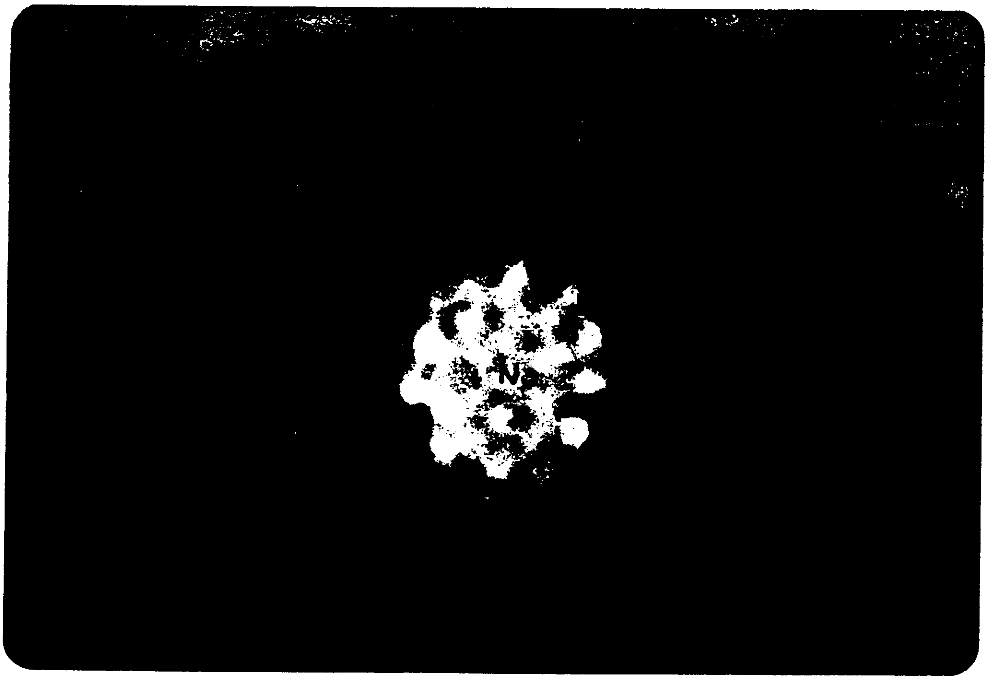

SF
Py

NAUTILUS

Plate 16. Dinoflagellate cyst, preserved as exinite, in a calcareous silty claystone. 1263m. Fl., field width 0.11mm.

Plate 17. Calcareous nannofossil in a limestone. Most of the carbonate grains fluoresce, but that from some of the fossils is relatively intense, being due, probably, to the presence of adsorbed, or otherwise included, organic compounds. 1584m, $\bar{R}_o$max ?0.36%. Fl., field width 0.34mm.




N

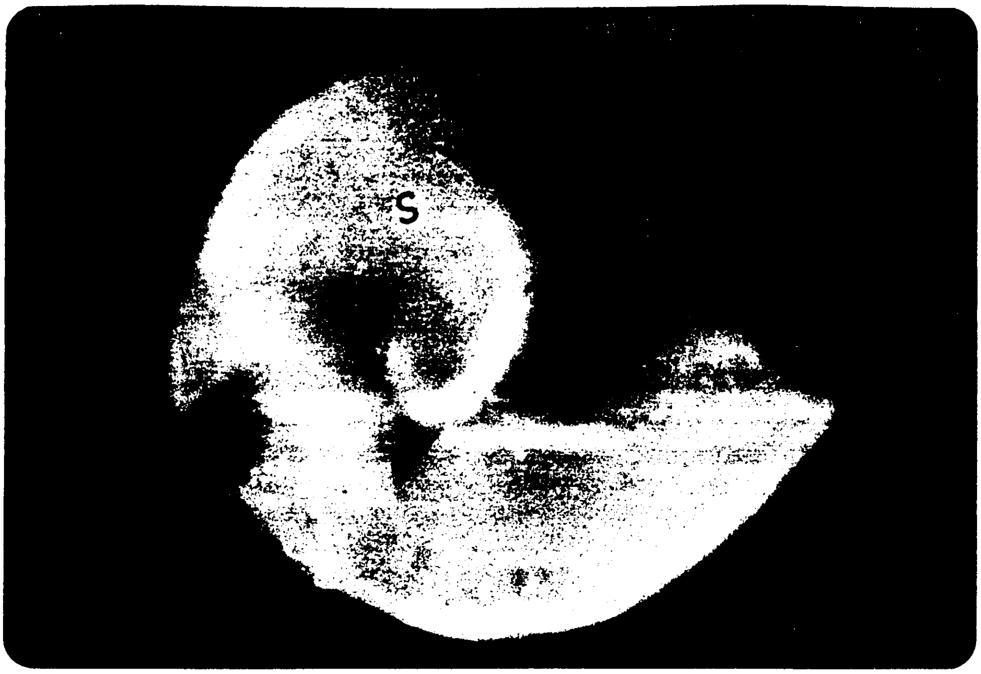
NAUTILUS

Plate 18. Sporinite in a section close to the plane of the bedding. Some of the surface ornament is visible. 2009m; $\bar{R}_o$max 0.52%. Fl., field width 0.095mm.

NORTH EUMERALLA

Plate 19. Cutinite occurring in a groundmass of vitrinite. Structure within the cutinite is relatively well preserved, and the intensity of fluorescence is variable within each layer of cutinite. 1923m, $\bar{R}_o$max 0.56%. Fl., field width 0.34mm.

Plate 20. Abundant sporinite occurring in a claystone. Sporinite is much less abundant overall in this sample, comprising <0.5% of the total, whereas in this field it comprises >5%. The sporinite is here seen perpendicular to bedding. 1923m, $\bar{R}_o$max 0.56%. Fl., field width 0.34mm.

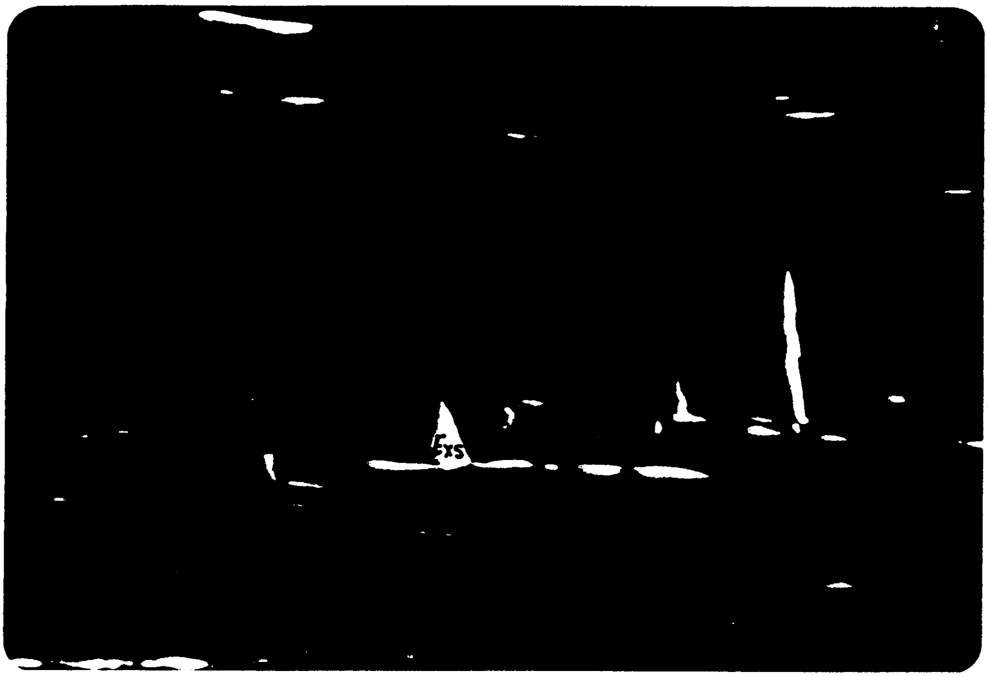

S

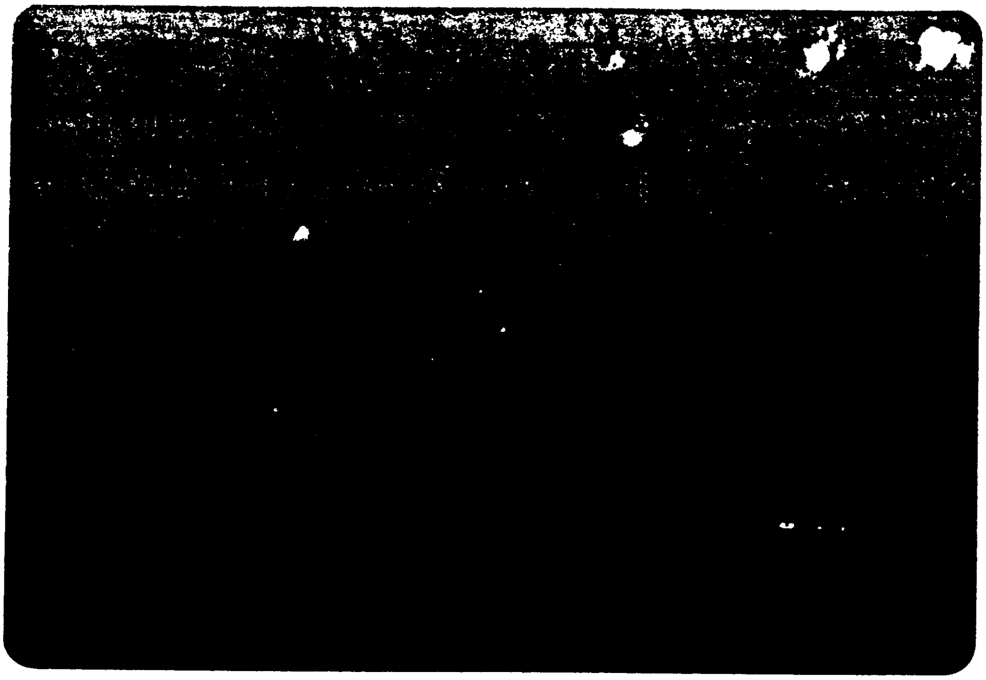

R

NORTH EUMERALLA

Plate 21. Veins of exsudatinite occurring in resin-rich vitrinite. The veins appear to have formed along cleats within the coal, but are much wider than most cleat fractures, and, from their triangular shape, may have induced a widening of the fractures, either by replacement, or by forcing the walls apart. 2669m, $\bar{R}_o$max 0.68%. Fl., field width 0.34mm.

Plate 22. As for Plate 21, but in reflected light. The poor polish may be due, in part, to this type of occurrence having a greater elasticity than is normal for vitrinite. Similar difficulties are encountered in polishing alginite.


Exs



NORTH EUMERALLA

Plate 23. Vitrinite showing a sculptured surface as a result of polishing, together with cutinite. The cutinite has a very low reflectance such that its surface is largely obscured by fluorescence resulting from the blue part of the spectrum in the incident "white" light. 1496m, $\bar{R}_o$max 0.43%. R.L., field width 0.34mm.

PECTEN

Plate 24. Large mass of strongly fluorescent organic matter. This falls within the definition of fluorinite, but may represent partially migrated oil. The dark masses within the organic matter are pyrite. The pyrite does not have a blue cast in this Plate because the fluorescence of the organic matter is so strong that the exposure time is too short for the blue "show through" of the pyrite to be recorded. 1339m $\bar{R}_o$max 0.39%. Fl., field width 0.56mm.

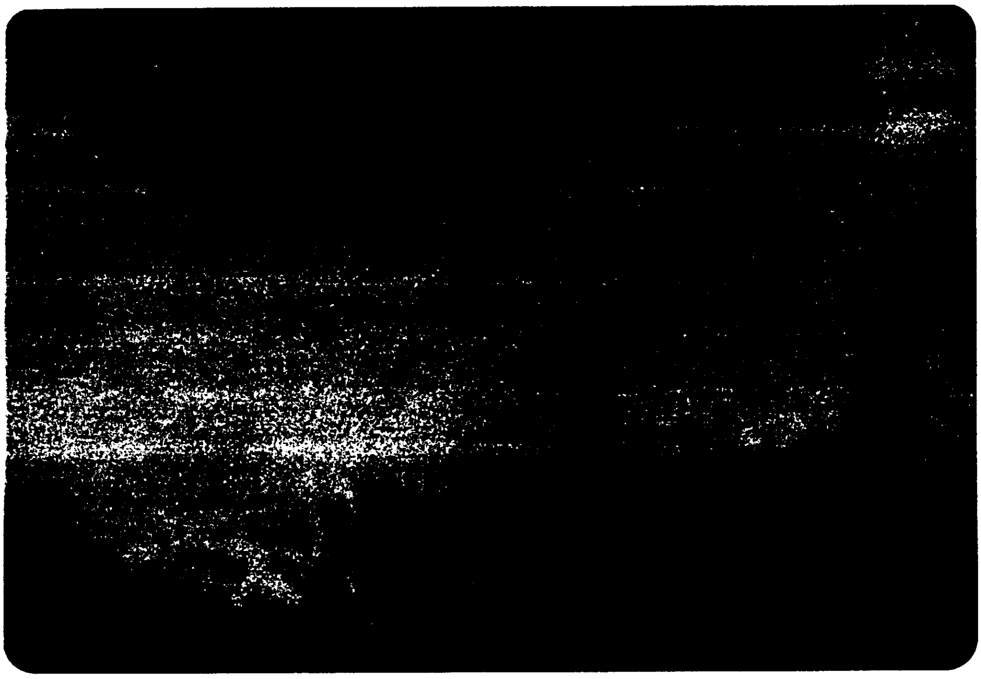

V


Fl

PECTEN

Plate 25. Irregular vein of ?bitumen having affinities with wurtzilite. The fenestrate structure of the margins appears to be structure within the bitumen rather than relict plant structure. 2842m $\bar{R}_o$max 0.81%. Fl., width field 0.34mm.

Plate 26. Fluorinite, resinite, sporinite and liptodetrinite occurring in a weakly fluorescing vitrinite-dominated groundmass. The groundmass and, to a lesser extent the sporinite, show strong positive alteration. This Plate was taken by irradiating the central part of the field using the 125x lens for 45 minutes, and then taking the photograph using the 32x lens. Where positive alteration occurs this results in a brighter central area. 2842m, $\bar{R}_o$max 0.81%. Fl., field width 0.43mm.



Fl

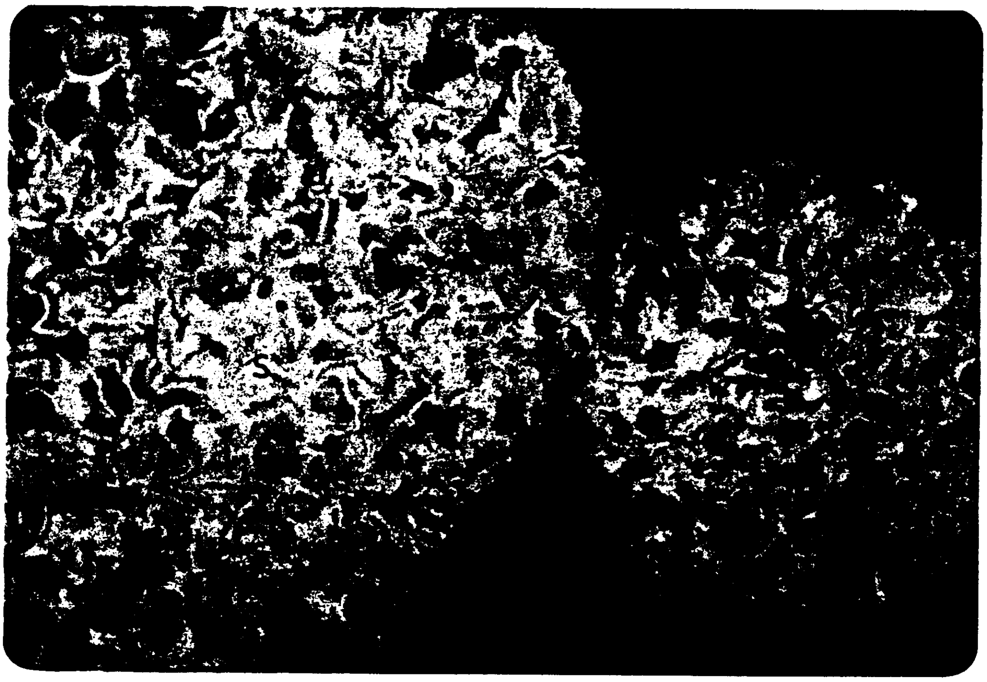
PECTEN

Plate 27. Fusinite. Fusinite is rare in both the coals and the epiclastic sediments. The majority of the inertinite is of lower reflectance and has much less distinct cellular structure, as, for example, in Plate 1. 2359m, $\bar{R}_o$max 0.55%. R.L. field width 0.58mm.

PORT CAMPBELL

Plate 28. Partially pyritized sporangium. 2343m $\bar{R}_o$max 0.83%. Fl., field width 0.37mm.


F

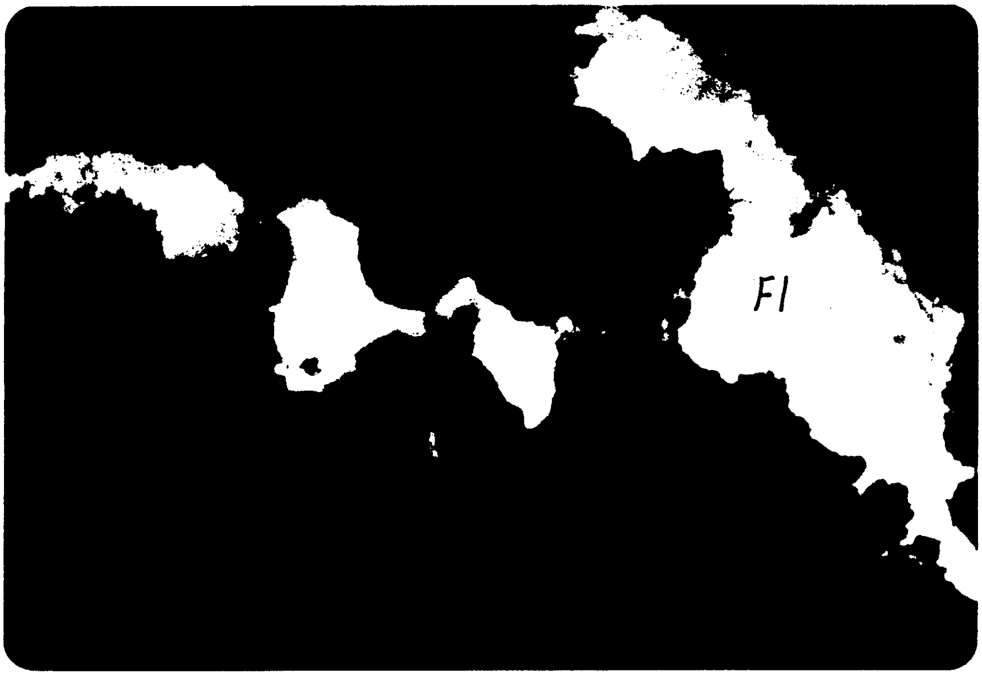


PORT CAMPBELL

Plate 29. Fluorinite or oil-related hydrocarbons in pyritized coaly material occurring in silty shale. 2343m $\bar{R}_o$max 0.83%. Fl., field width 0.45mm.

ROWANS

Plate 30. Textoulminite. Isolated grains of massive vitrinite-group macerals occur in all of the samples from this well. 1756m $\bar{R}_o$max 0.49%. R.L., field width 0.34mm.


Fl

VOLUTA

Plate 31. Siltstone with bright fluorescence on the rims of many of the quartz grains. Such fluorescence may be associated with free hydrocarbons. 3653m, $\bar{R}_o$max 0.95%. Fl., field width 0.1mm.

Plate 32. Vitrinite phytoclast typical of those in many of the sediments which contain sparse and poorly defined populations of vitrinite. 3653m, $\bar{R}_o$max 0.95%. R.L., field width 0.34mm.