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ORGANIC PETROLOGY OF SAMPLES FROM SIX WELLS FROM THE OTWAY BASIN.

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A REPORT PREPARED FOR ESSO AUSTRALIA

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Introduction

The study is designed to provide information on the level of maturation of organic matter in the sedimentary rocks of parts of the Otway Basin. Additionally, information has been gained concerning the source-potential of the organic matter. Forty four samples were examined from five wells and additional data from 13 samples from one other well have been included in this compilation. The samples provided an indication of the level of maturation for all the wells sampled and an indication of reflectance gradient for four of the wells. The information on source-rock potential can only be regarded as very preliminary since the number of samples is not great and samples taken for maturation studies may not be representative of the potential source rocks.

The samples were prepared as grain mounts or in the case of core samples as oriented blocks. Where small amounts of coal were present in the sample, hand-picked concentrates were mounted.

The polished sections were immersed in oil and the reflectance reasurements obtained as soon after immersion as possible. Fluorescence examination and record photography were undertaken after the reflectance measurements.

Reflectance measurement conditions: Leitz MPV 1 photometer, 0.85 aperture fluorite lens, plane polarized light, oil refractive index 1.518 @ 23°C, λ = 546 um, glass standards 0.53%, 1.01%, 1.82%, spinel, YAG.

Fluorescence filters: excitation, 3mm B.G.3 (blue light); TK 400 dichroic mirror; K 490 barrier filter; reflected light photographs taken with K460 filter to suppress colour from the dichroic mirror; 100w mercury source.

Vitrinite reflectance.

The vitrinite reflectance data indicate that the great majority of the section drilled lies in the immature zone (< 0.5% $\bar{R}_o$max). The depth to the zone of initial maturity appears to be generally in the range 1800m to 2200m but may be about 1200m in Port Campbell-1. The deeper wells,

Eumeralla-1, Mussel-1, Pecten-1A and Prawn-1, penetrated the zone of maturity and in the case of Eumeralla-1 the zone of prolific oil generation. If the land plant origin of the majority of the kerogen is considered to influence the level of maturity at which oil generation occurs, then only Eumeralla can be considered to have penetrated the oil mature section.

Reflectance gradients are low to moderate, being generally less than those found in the related Bass and Gippsland Basins.

In the case of the Port Campbell-1 well the small stratigraphic range of the samples and the extent of type variation prevent an estimate being made of the reflectance gradient. The relatively small range over which reflectance data are available precludes an extensive analysis and comparison of the data with that from these other basins.

Exinite fluorescence colours agree with the indications of maturity given by the vitrinite reflectance.

With samples containing low rank coals, type variation within the vitrinite and the effects of sample storage present special problems. Storage tends to cause a rise in reflectance so that the present data probably represent maximum estimates of maturity. The effects of type variation are well illustrated by the samples from Port Campbell-1. At 890m a sample of ulminite has a reflectance of 0.47% whereas samples containing large amounts of desmocollinite from 1740m and 1807m have vitrinite reflectances of 0.44% and 0.45% respectively. In these last two samples, measurements were made, as far as possible, on bands of telovitrinite, but as is common in such lithologies, the reflectance of the telovitrinite as well as that of the desmocollinite is relatively low.

Organic Matter Type.

In the wells sampled the units in the mature parts of the section are generally restricted to the Belfast and Otway Groups. Discrete particles of dispersed organic matter are very rare in all of the limestones sampled and in most of the sandstones and siltstones.

No algal material was found and apart from rare dinoflagellates, all of the dispersed organic matter is of land plant origin. This land plant material is virtually confined to the Wangerrip, Sherbrook and Otway Groups with the Otway Group samples generally containing more abundant organic matter. Many of the samples are vitrinite rich but especially in the Sherbrook Group a number of samples proved to contain abundant inertinite. The inertinite rich lithologies range widely in type but two lithologies are distinctive. Durite (Plates 1 and 2) containing abundant exinite (sporinite and resinite) is the most abundant inertinite rich lithology with semifusinite dominated lithologies being less common. These latter lithologies resemble tenuidurains and contain relatively little exinite (dominantly cutinite). The vitrinite rich lithologies range from band vitrinite containing very little exinite to clarites containing abundant exinite (sporinite and cutinite). Exinite does not appear to be abundant in many of the coal associated lithologies. Sporinite is abundant in some claystones but most siltstones and all sandstones are virtually devoid of exinite.

Fluorinite (Plate 3) is remarkably abundant in a number of samples. It occurs in association with vitrinite and fluoresces a brilliant green under blue light excitation. Exsudatinite (Plate 4) is relatively rare but its presence suggests that active hydrocarbon migration has occurred at least on a minor scale, and is consistent with the known history of oil shows.

Relation of vitrinite reflectance to present well-temperatures.

Using the temperature data supplied (BHT figures), estimates have been made of the temperature at the 0.5% reflectance level for Mussel-1, Pecten-1a, Port Campbell-1 and Prawn-1. This temperature lies in the range 50°C to 80°C. Equivalent data for other basins are given in Table 1. The range of rank found in the samples from the Otway Basin does not permit the calculation of average temperatures at higher levels of vitrinite reflectance but

studies on other basins suggest that the value obtained at the 0.5% level is representative of the trend for higher reflectances.

All of the basins listed in Table 1 contain successions which are at or close to their maximum depth of burial. The Perth and Cooper Basins contain little or no upper Cretaceous or Tertiary and differ to this extent. It is considered that, taken in conjunction with sediment age and basin history, the data in Table 1 give information concerning the rate and timing of maturation. Average age at the 0.5% vitrinite reflectance surface has not been calculated for the Otway Basin data but lies in the range 80m.y. to 120m.y. It is thus broadly comparable with the ages for the Cooper, Carnarvon and Perth Basins and significantly older than the Bass and Gippsland Basins.

The average temperature at the 0.5% vitrinite reflectance surface in the Otway Basin is marginally above that for the Perth Basin but significantly below that for the Cooper and Carnarvon Basins. The temperature at the reflectance level for the Otway Basin also lies within the range for the Bass and Gippsland Basins but the equivalent sediment age is much greater in the Otway Basin. The data in Table 1 imply a lower average rate of maturation for the organic matter in the Otway Basin sediments as compared with the Gippsland and Bass Basins. The occurrence of the 0.5% reflectance surface at similar depths and at generally similar temperatures in the three basins indicates that the Otway Basin sequences have undergone relatively little early coalification.

Table 1. Present well-temperature at the 0.5% vitrinite reflectance surface.

Basin	Well-temperature (^{o}C) at the 0.5% vitrinite reflectance surface		Average age at 0.5% surface (m.y.)
	Mean	Range	
Otway*	64	52-77	n.a.
Cooper	80	47-112	124
Carnarvon	96	85-108	123
Perth	60	36-82	153
Gippsland	75	59-92	54
Bass	78	60-96	49** 57***

* Estimated from uncorrected BHT data. Temperatures from other basins relate to corrected temperature data.

** Does not include data for Durroon.

*** Includes data for Durroon.

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Conclusions.

Sufficient vitrinite reflectance data were obtained to indicate that the sections penetrated by the suite of wells are immature to early mature. Associated with the low overall level of maturity, are moderate to low reflectance gradients. The relatively thin stratigraphic interval over which vitrinite is present in some wells is insufficient for the establishment of a reliable estimate of reflectance gradient (Nautilus-1, Port Campbell and possibly Mussel-1).

Exinite-rich organic matter of land plant origin is present over extensive intervals within the Sherbrook and Otway Groups. The exinite is preferentially associated with coals rather than shales in the samples examined, and this may be considered to downgrade the oil generation potential of the sequence.

As compared with the Gippsland and Bass Basins, hydrocarbon generation within the Otway Basin has occurred more slowly and this is likely to have had an unfavourable influence over the balance between accumulation into, and loss from, potential reservoirs. Sufficient variability is present in both maturation patterns and source rock characteristics to suggest that conditions favourable to the accumulation of hydrocarbons in commercial quantities may exist within the Otway Basin.

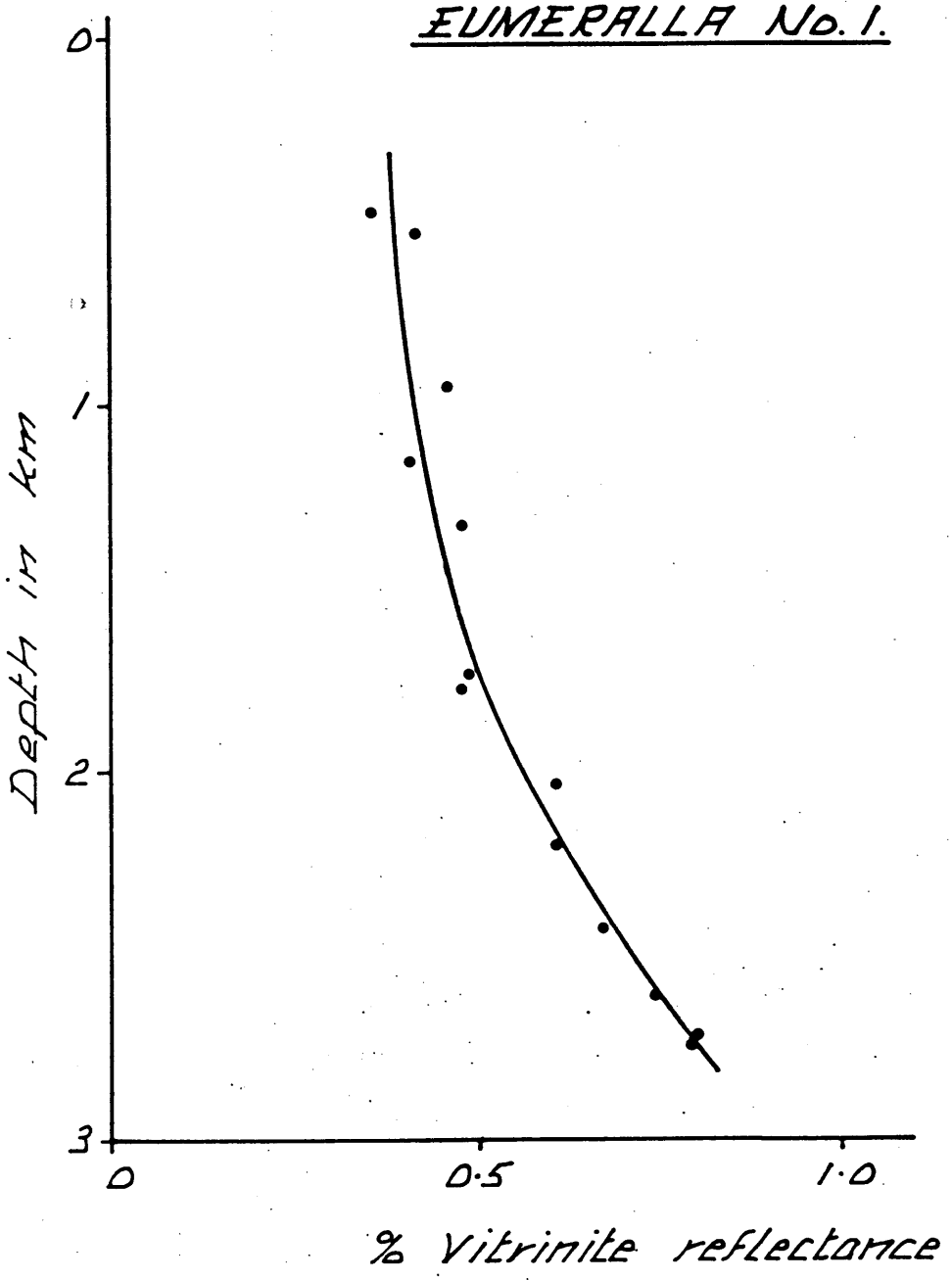
EUMERALLA No. 1.
0
1
2
3
Depth in km
0
0·5
1·0
% Vitrinite reflectance

Fig. 1.

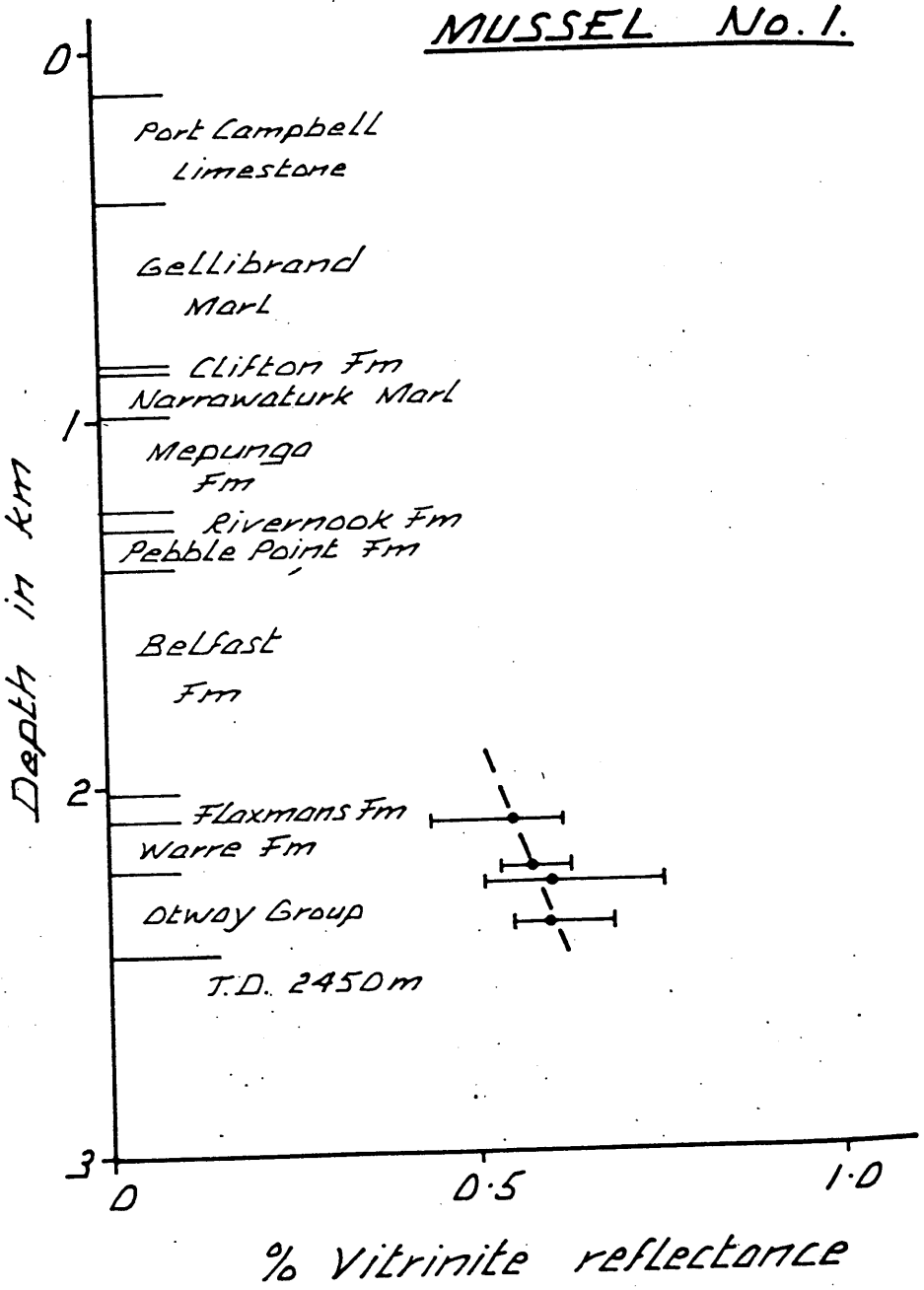
MUSSEL No. 1.
0
1
2
3
Depth in km
Port Campbell Limestone
Gellibrand Marl
Clifton Fm
Narrawaturk Marl
Mepunga Fm
Rivermook Fm
Pebble Point Fm
Belfast Fm
Flaxmans Fm
Warre Fm
Otway Group
T.D. 2450m
0
0·5
1·0
% Vitrinite reflectance

Fig. 2.

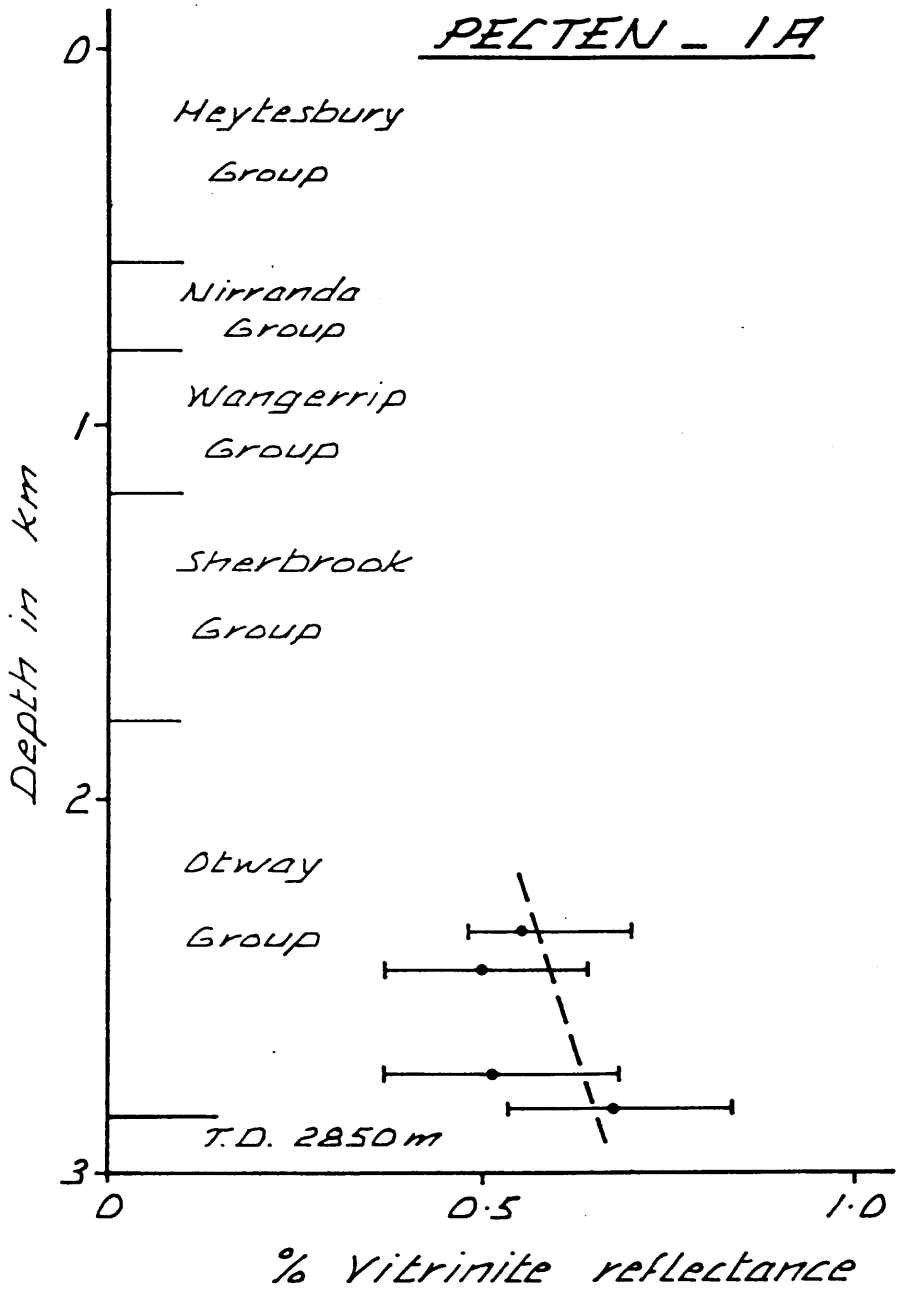
PECTEN - 1A
0
1
2
3
Depth in km
Heytesbury Group
Nirranda Group
Wangerrip Group
Sherbrook Group
Otway Group
T.D. 2850m
0
0·5
1·0
% Vitrinite reflectance

Fig. 4.

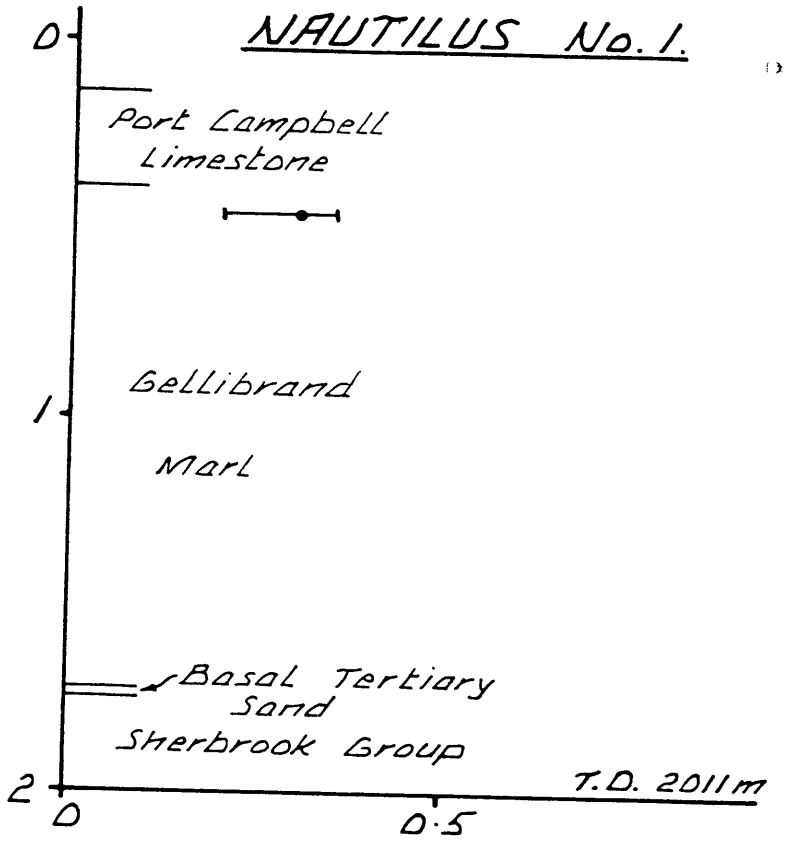
NAUTILUS No. 1.
0
Port Campbell Limestone
1
Gellibrand Marl
Basal Tertiary Sand
Sherbrook Group
2
T.D. 2011m
0
0·5
% Vitrinite reflectance

Fig. 3.

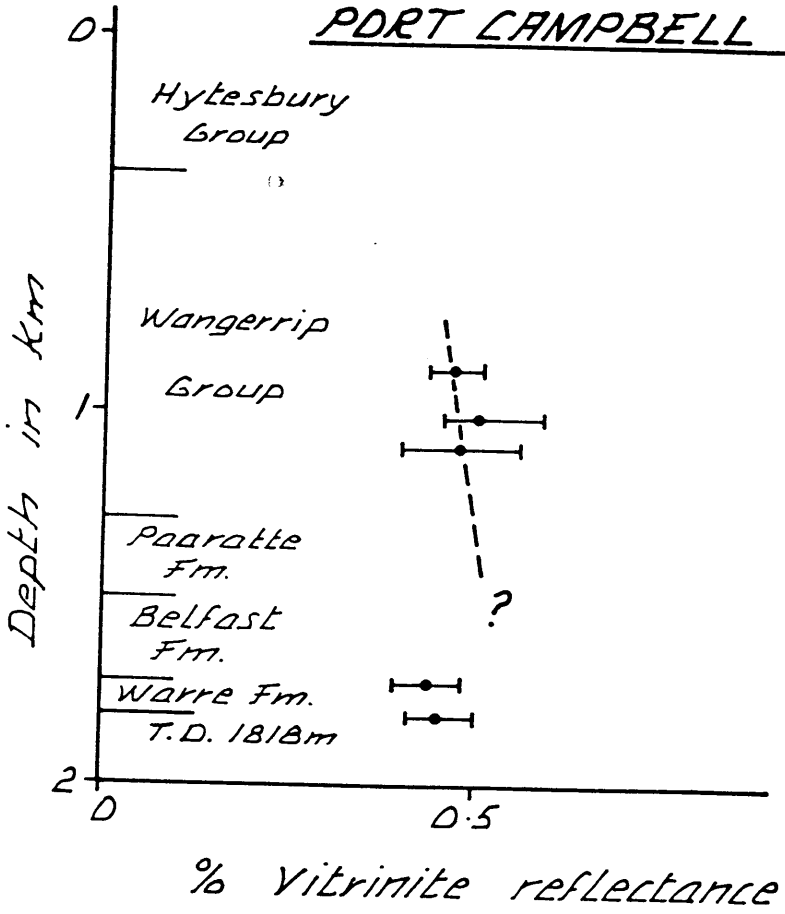
PORT CAMPBELL No. 1.
0
1
2
Depth in km
Hytesbury Group
Wangerrip Group
Paaratte Fm.
Belfast Fm.
Warre Fm.
T.D. 1818m
?
0
0·5
% Vitrinite reflectance

Fig. 5.

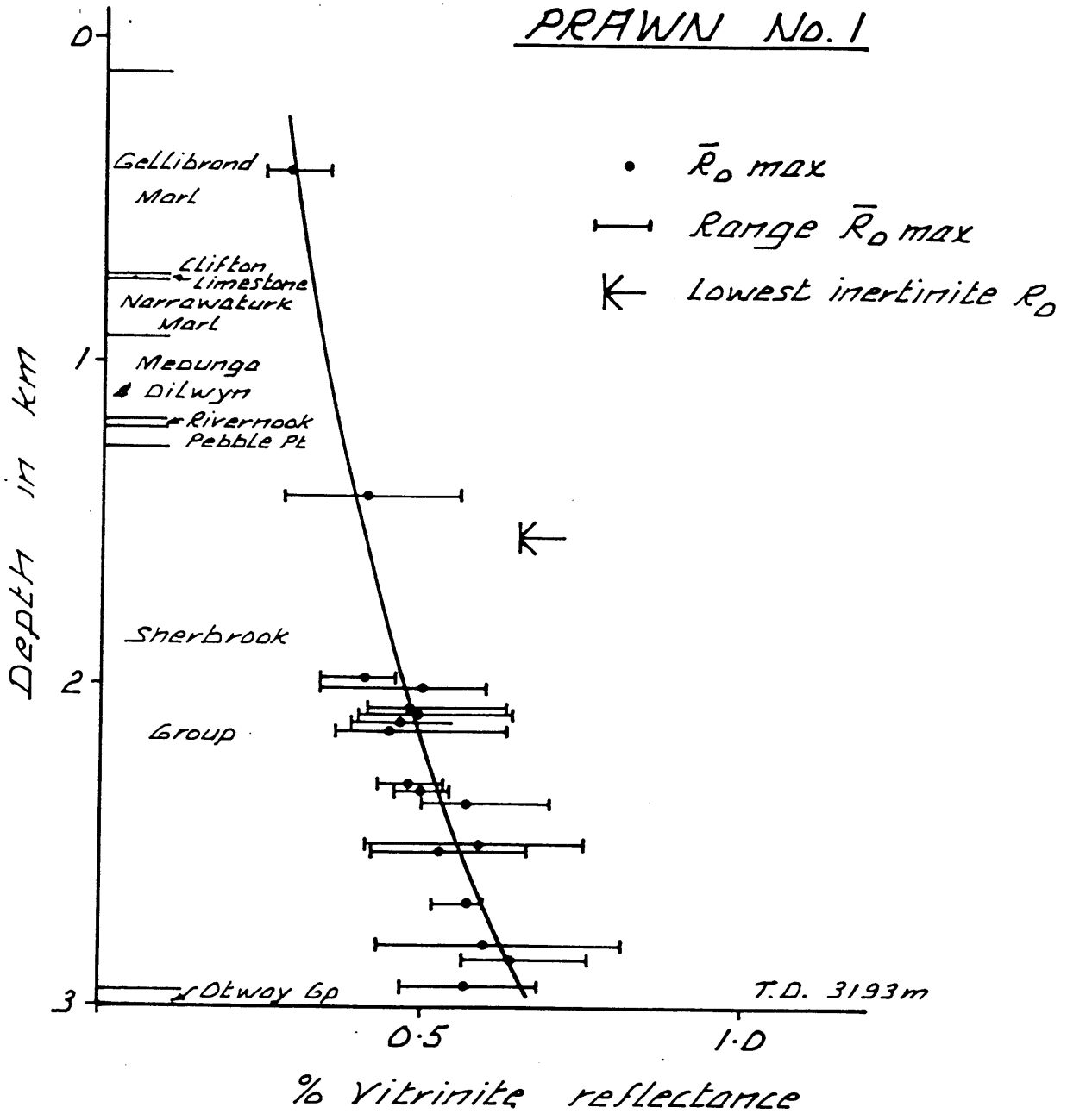
PRAWN No. 1
$\bar{R}_o$ max
Range $\bar{R}_o$ max
Lowest inertinite R_o
Depth in km
0
1
2
3
Gellibrond Marl
Clifton Limestone
Narrawaturk Marl
Meounga & Dilwyn
Rivernook
Pebble Pt
Sherbrook Group
Otway Gp
T.D. 3193m
0·5
1·0
% Vitrinite reflectance

Fig. 6.

Appendix 1. Eumeralla-1

UW No.	Depth m	$\bar{R}o$ max %	Range %	R max	N	Exinite fluorescence (Remarks)
	471	0.36				
	541	0.42				
	952	0.46				
	1160	0.41				
	1340	0.48				
	1742	0.49				
	1785	0.48				
	2047	0.61				
	2204	0.61				
	2440	0.67				
	2610	0.74				
	2738	0.80				
	2757	0.79				

Appendix 2. Mussel - 1

UW No.	Depth m	Ro max %	Range Ro max %	N	Exinite fluorescence (Remarks)
8674	1734			-	No exinite (Limestone, bright yellow-green fluorescence in lumens of some foraminifera.
8675	2100	0.55	0.44-0.62	4	One yellow-orange spore. (D.o.m. rare, minor carbonaceous stringers in sandstone).
8676	2238	0.58	0.54-0.63	20	Exinite sparse to common, chiefly dull brown cutinite, bright green fluorinite up to 5%. (Coal and shaly coal).
8677	2255	0.60	0.51-0.76	11	Exinite rare overall, abundant in a few grains, yellow to dull brown sporinite, some green to yellow fluorinite (V stringers in clayst. and siltst., bitumen, R 2.03%, in lst.).
8678	2286	0.60	0.55-0.69	10	Coal with up to 10% E, trace only in other lithologies, sporinite yellow orange to dull orange. (Rare coal).

Appendix 3. Nautilus - 1

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UW No.	Depth m	$\bar{R}o$ max %	Range $\bar{R}$ max %	N	Exinite fluorescence (Remarks)
8670	439			-	No exinite, some foraminifera with minor green fluorescence.
8671	453	<0.84 (SF)		-	No exinite, limestone
8672	453	0.30	0.20-0.35	5	Exinite abundant, sporinite orange to dull orange. (Two grains of coal one I rich, the other V rich).
8673	550			-	Limestone with very rare liptodetrinite, bright yellow-green.

Appendix 4. Pecten - 1A 18/26

UW No.	Depth m	$\bar{R}o$ max %	Range R max %	N	Exinite fluorescence (Remarks)
8646	1907			-	Bitumen which is soluble in immersion oil, initial reflectance 0.90% falling to 0.18% after 60 seconds.
8647	2359	0.55	0.48-0.70	18	Exinite abundant, sporinite yellow to dull orange. (E up to 20%, I up to 40%, some fluorinite, with bright green fluorescence).
8648	2453	0.50	0.37-0.64	19	Exinite abundant, sporinite green yellow to dull orange. (Clarite rich coal with minor claystones, minor pyrite).
8649	2738	0.51	0.37-0.68	20	Exinite to 20%, chiefly sporinite, dominant orange but rangingyellow to dull orange. (I abundant, ? bitumenR 0.12%).
8650	2831	0.68	0.53-0.83	14	Sparse to abundant sporinite, orange, ranging yellow orange to dull orange, minor fluorinite. (One grain $R_o$max 1.0%, presumed to be contaminant and omitted).

Appendix 5. Port Campbell-1 19/26

UW No.	Depth m	$\bar{R}o$ max %	Range R max %	N	Exinite fluorescence (Remarks)
8651	327				No exinite, (Sandstone.)
8652	444			-	No exinite. (Calcareous sandstone, posible bitumen rich layer.)
8653	890	0.47	0.43-0.51	15	Essentially no exinite. (Grains of massive vitrinite, ulminite texture.)
8654	1018	0.50	0.46-0.59	8	Rare, mainly orange, sporinite and cutinite, minor yellow cutinite. (Semifusinite rich, V as very thin stringers)
8655	1099	0.48	0.40-0.56	23	As for 8654.
8656	1219			-	Exinite very rare. (Dirty sandstone, d.o.m. mainly I.)
8657	1378			-	As for 8656.
8658	1740	0.44	0.39-0.48	16	Exinite abundant, mainly sporinite, bright yellow, orange, dull orange, cutinite and common bright green fluorinite. (Large grains of clarite E <10%, I trace, mi pyrite).
8659	1807	0.45	0.41-0.50	17	As for 8658.

Appendix 6. Prawn No. 1

UW No.	Depth m	$\bar{R}_o$max %	Range $\bar{R}$max %	N	Exinite fluorescence (Remarks)
8623	370	-	-	-	No exinite
8624	404	0.29	0.25-0.35	4	No exinite (2 grains of vitrinite, remainder of sample limestone).
8625	437	-	-	-	No exinite
8626	934	-	-	-	No exinite
8627	1410	0.41	0.28-0.56	5	Rare liptodetrinite yellow to yellow-green, possibly some dinoflagellates present.
8628	1541		<0.65%	-	Liptodetrinite, yellow, very rare.
8629	1980	0.41	0.34-0.46	15	Sporinite and liptodetrinite green-yellow to dull orange, mode at yellow, rare to abundant. Sporinite in coal is bright yellow. (Coal is rare but contains up to 10% exinite).
8630	2004	0.50	0.34-0.60	14	Sporinite and liptodetrinite rare except in coal, green-yellow to dull orange. Exsudatinite common in some grains of band vitrinite.
8631	2059	0.48	0.42-0.63	20	Sporinite abundant in coals and shaly coal, sparse in other lithologies, yellow to dull orange. Resinite/fluorinite present in shaly coal.
8632	2092	0.49	0.40-0.64	18	Sporinite common silty shales, rare in other lithologies, yellow to dull orange. Rare brilliant yellow fluorinite with ?exsudatinite.
8633	2117	0.47	0.39-0.55	22	Exinite abundant in coal and related lithologies, sporinite dominant, yellow to dull orange, cutinite typically dull orange.
8634	2141	0.45	0.37-0.63	23	Exinite very abundant, sporinite > cutinite, brilliant yellow to dull orange, one grain of coal with large lenses of fluorinite, fluorescing brilliant green. (V dominant but E to 20% and I to 60% in some grains).

8636	2309	0.48	0.43-0.53	16	Exinite abundant in coal associated lithologies but rare in other lithologies. Sporinite dominant over cutinite, yellow to dull orange. Trace of fluorinite.
8636	2327	0.50	0.46-0.54	10	Exinite sparse, seldom associated with coal, sporinite yellow to dull orange mode at orange.
8637	2389	0.57	0.50-0.70	15	Exinite rare, yellow orange liptodetrinite (Minor fryparming of some grains).
8638	2498	0.59	0.41-0.75	33	Exinite abundant, sporinite and resinite dominant, orange or dull orange, rarely yellow. Cutinite chiefly dull orange, rare bright yellow, some fluorinite, typically green (E up to 50% or 90% in durites and 30% in clarites and shaly coal - overall V50, E15, I35).
8639	2528	0.53	0.42-0.67	25	Similar to 8638, exinite very abundant, less durite.
8640	2681	0.57	0.52-0.60	8	Exinite common in coal mainly dull orange but ranging to yellow.
8641	2803	0.60	0.43-0.81	25	Cutinite very abundant, dull orange, rarely yellow common fluorinite, green, sporinite common, yellow to orange.
8642	2828	0.64	0.57-0.76	5	Exinite common to abundant in siltstones, dominantly sporinite orange to dull orange, but large lenses of fluorinite, bright green, common in siltstone grains. Exinite common in coals.
8643	2930	0.57	0.47-0.68	12	Exinite common to very abundant, sporinite and cutinite yellow orange to dull orange, some yellow fluorinite (Sample frypanned with oxidized rims and some vesiculation, pyrite abundant. Exinite up to 60% in clay/vitrinite association).

PLATE CAPTIONS

KEY:

F - fluorinite
Exs - exsudatinite
E - exinite (undifferentiated)
R - resinite
S - sporinite
Sltst - siltstone

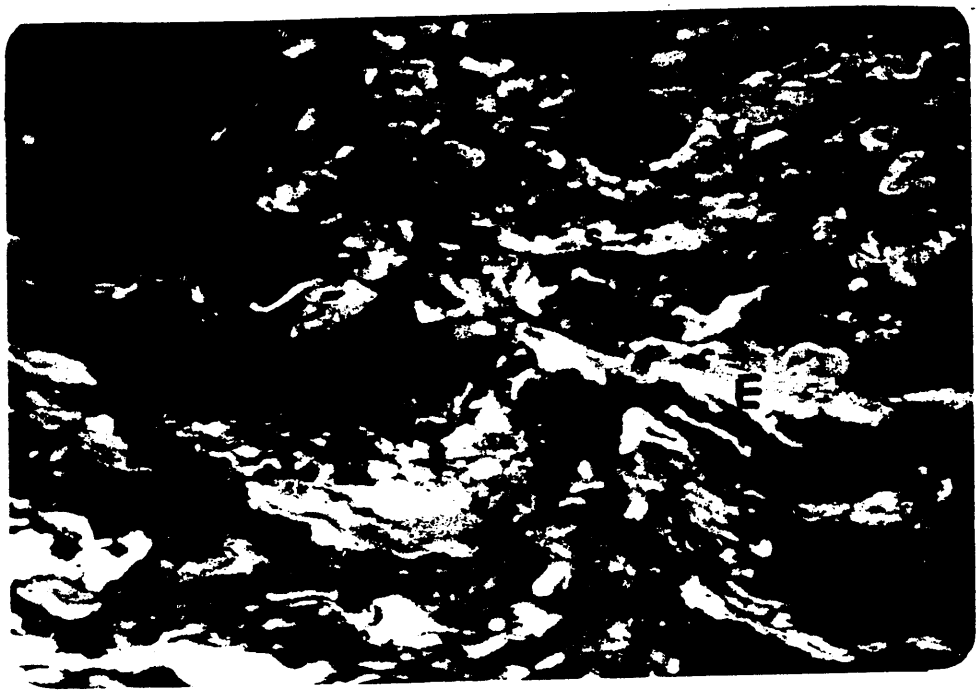
All plates taken in reflected fluorescence mode, BG3 excitation filter, TK 400 dichroic mirror, K 490 barrier filter, field width 0.34mm.

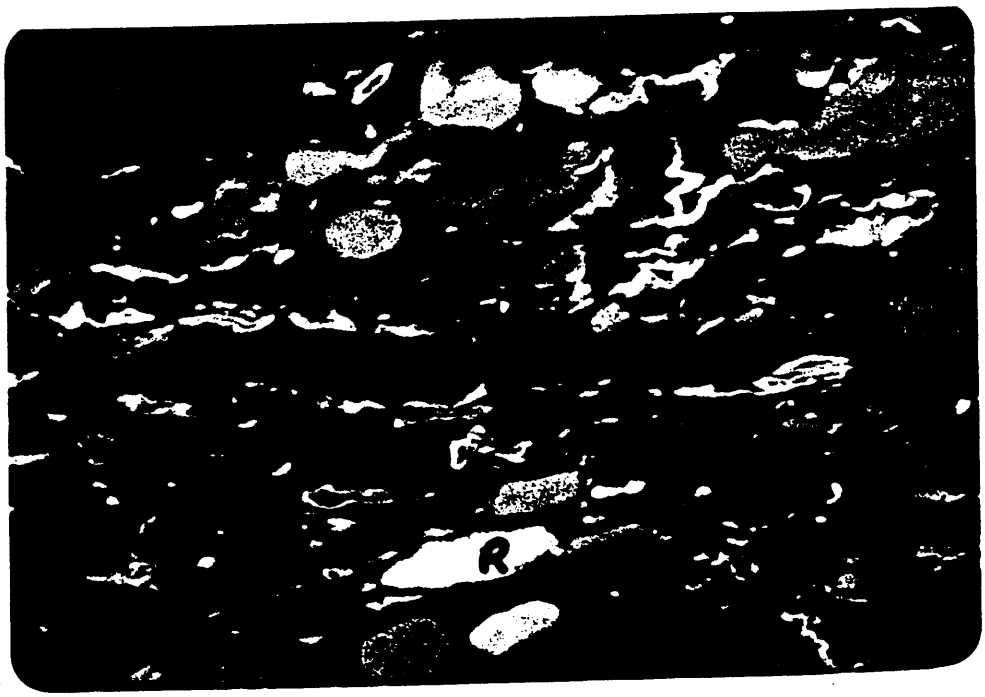
Plate 1. Duroclarite containing a high percentage of sporinite and other less easily differentiated forms of exinite. Prawn-1, 2498 m, $\bar{R}_o$max 0.59%.

Plate 2. Durite containing abundant resin bodies which show a large range of fluorescence intensity and colour. Prawn-1, 2498 m, $\bar{R}_o$max. 0.59%.

Plate 3. Large mass of fluorinite. Smaller masses of fluorinite occur in cell lumens with the cell walls preserved as vitrinite. Prawn-1, 2141 m, $\bar{R}_o$max 0.45%.

Plate 4. Small veins of bright yellow fluorescing exsudatinite in a vitrinite phytoclast hosted by a siltstone. Prawn-1, 2004 m, $\bar{R}_o$max 0.50%.

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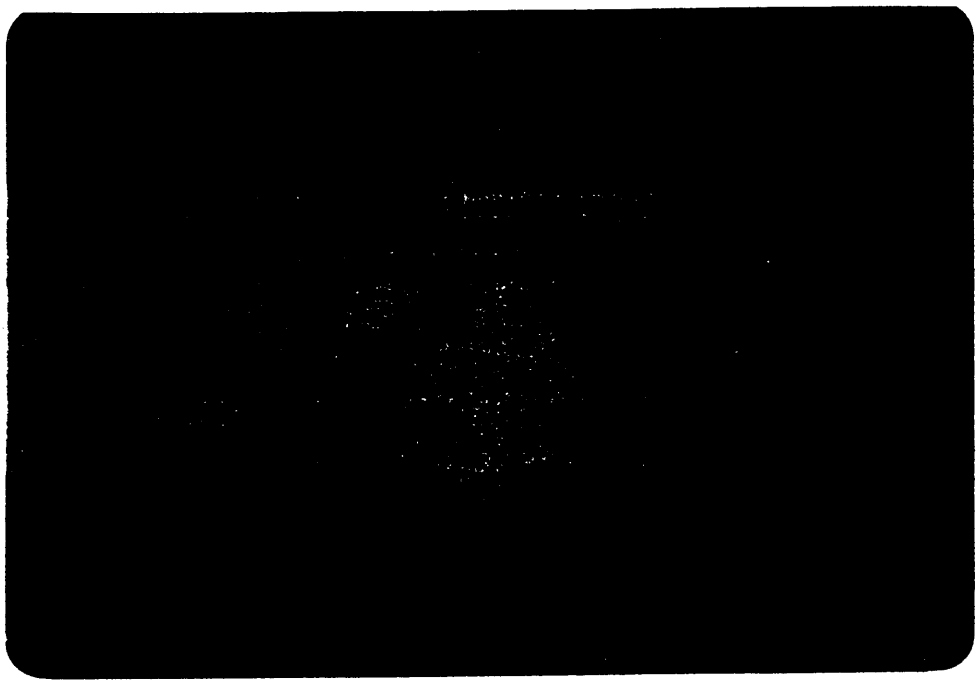

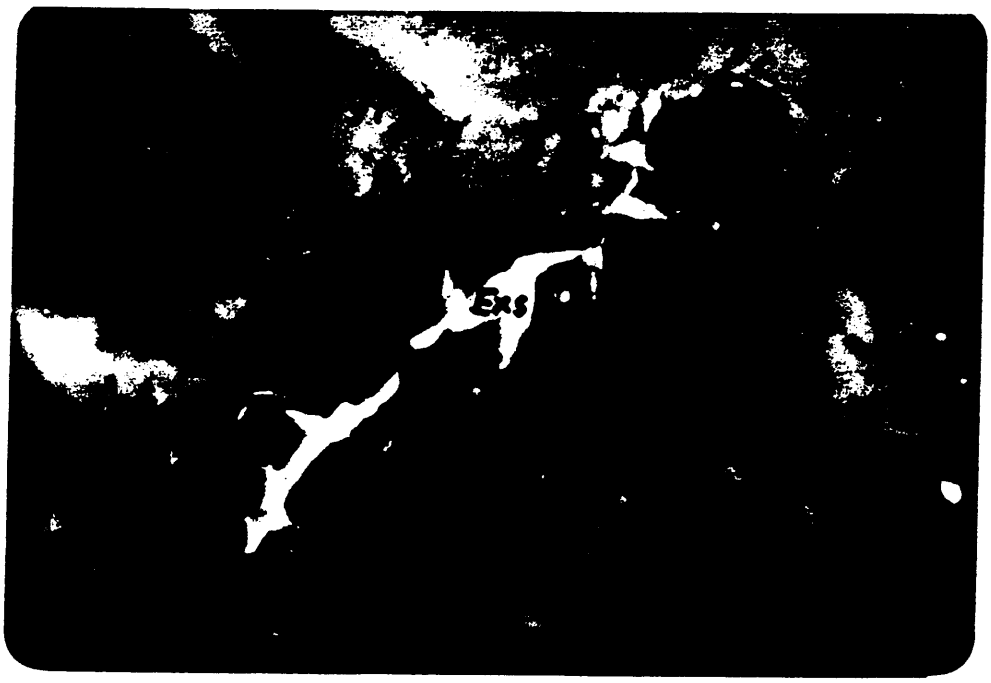
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