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ANALYSIS OF SOURCE ROCK PROPERTIES  
OF SAMPLES FROM THE LOWER TERTIARY  
WELL CORMORANT-1, BASS BASIN, AUSTRALIA

by

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code: 774.103

Investigation

9.12.452

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**RIJSWIJK, THE NETHERLANDS**

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## I INTRODUCTION

A source rock evaluation has been carried out on cutting and core samples from well Cormorant-1 in the Bass Basin, Base Strait between Victoria and Tasmania, Australia. The approximate location of the well is shown in figure 1.

The samples derive from the Torquay group, Demons Bluff, Boonah Sandstone and Easter View Coal Measures formations. They cover the interval 2997 - 9843 ft (i.e. total depth).

Source rock evaluation commonly comprises determination of:

1. the presence (or absence) of hydrocarbons source material in the rock samples;
2. the quality of the organic matter as well as the distribution of its specific constituents;
3. the degree of organic metamorphism (= level of maturity).

A source rock is identified by measuring the amount of temperature reactive ("live") organic matter present, i.e. the amount of organic matter that yields hydrocarbons upon pyrolysis. The method excludes any ("dead") organic matter such as inertinites.

In addition, the total organic carbon content can be determined which gives the sum of "live" and "dead" organic carbon. Rocks containing less than 0.5 % organic carbon are not considered to have a potential for commercial oil accumulations.

The source rock indications (SRI), which are a measure of the amount of pyrolysable organic matter, are determined on the original samples and in certain cases also after extraction with organic solvents. A systematically lower value after extraction is due to the presence of extractable hydrocarbons. These may consist of trapped oil, oil generated in situ by a source rock, or e.g. gasoil used in the drilling fluid.

In general, samples with source rock indications of 30 or less do not represent (immature or mature) source rocks. Values between 30 and 100 generally indicate marginal source rocks, while values above 100 commonly indicate good source rocks.

Intervals or samples with high source rock indications are investigated under a microscope to ensure that the high values indicate genuine source rock properties and are not due to contaminants of an organic nature such as lost circulation material.

The quality of a source rock for oil/gas generation depends on the type of organic matter present. Five categories of organic matter can be distinguished, viz.: humic, mainly humic, mixed, mainly kerogenous, kerogenous. This classification

is based on the hydrogen content of the organic matter.

Source rocks with organic matter of kerogenous, mainly kerogenous and/or mixed type generate predominantly oil. Organic matter of humic type generates gas only. Strata with organic matter of mainly humic quality generate either gas, or gas and oil.

In addition to the type and the concentration of the organic matter, the source rock quality is also characterised by the distribution of the typical organic constituents, or macerals<sup>1</sup>, in the sediments. The maceral distribution can be used to further qualify the source rock, especially when mainly humic quality is found. For this purpose a microscopic investigation on polished rock fragments is carried out.

The maturity of source rocks is expressed in terms of degree of organic metamorphism. With increasing degree of organic metamorphism the organic matter is gradually carbonised while generating hydrocarbons. With increased carbonification the light reflectance of vitrinite, one of the coal macerals, increases. The degree of organic metamorphism can be assessed by measuring this reflectance.

- 1) maceral: an organic constituent which can be recognised with the microscope (with objectives 25x to 50 x).

## II RESULTS

The results are plotted on the geochemical log (enclosure 1) and detailed in the attached tables and figures.

### a) Source rock indications (SRI)

Samples from the Demons Bluff formation show marginal source rock indications of ca.70 units. The samples from the Easter View Coal Measures formation show excellent SRI-values of more than 900 units, only towards the base of this well the SRI-values decrease to a level around 400 units.

### b) Type of organic matter

The type of organic matter has been determined in 10 samples. In all samples it ranges from "humic" to "mainly humic".

### c) Organic carbon content

The organic carbon content has been measured in ten samples. It apparently depends above all on the amount of coal in the samples. The content can reach values up to 59 wt% in cuttings at 6030 ft from the Easter View Coal Measures formation.

### d) Maceral analyses

Maceral analyses have been carried out on 13 samples. **The maceral composition generally represents a mixture of sapropelic organic matter (SOM) and land-plant derived material in varying proportions.** Vitrinite is the major contributor to the landplant material. In the cuttings below ca. 6980 ft vitrinite grades into SOM. From the same depth downwards the SOM

shows conversion features. Vitrinite reflectance measurements make it highly probable that the conversion is due to maturity. The coals are liptinite rich.

e) Vitrinite reflectance

Vitrinite reflectance has been measured in 9 samples between a depth of 4780 and 9030 ft. The reflectance histograms are given as figures 3 - 11. Figure 2 shows vitrinite reflectance as a function of depth. It shows that the conventional border of maturity for oil generation is about reached in the Easter View Coal Measures at a depth around 6700 ft. The values of the vitrinite reflectance measured at 7830 and 8030 ft are not reliable. This can be seen in figures 9 and 10. The histograms, representing the measurements, are highly smeared out. Although cuttings from 9030 ft are partly oxidised, the VR/E-value of 0.97 seems to be more in agreement with the maceral description, but still at the high side.

### III DISCUSSION AND CONCLUSION

In the Thorquay group (1305 - 3500 ft), represented by samples from 2997 down to 3500 ft, no significant source rock indications have been detected. This is in agreement with the maceral description of core sample 2997 ft. Therefore this formation can not be considered to contain source rocks.

In the Demons Bluff formation (3500 - 4280 ft) interval 3530 to 4030 ft show marginal source rock indications between 35 and 110 units. The type of organic matter in cutting sample 3680 ft is "humic". The sediments are still immature for oil generation. Unexpectedly the maceral analysis of this sample 3680 ft shows a favourable amount and habitat of sapropelic organic matter (SOM) as main maceral and only a few vitrinite.

The maceral SOM has a chemical composition which generally represents a fair "kerogenous" source rock. From this discrepancy it has to be concluded that the organic matter is so severely oxidized that only marginal amounts of gas can still be generated from it. As conclusion one may state that the Demons Bluff formation can be regarded as containing marginal source rocks for gas.

The Easter View Coal Measures (4527 - 9843 ft, i.e. total depth) are characterized by a series of outstanding SRI values. Only a small interval at the top of ca. 200 ft shows no SRI values and below 8000 ft source rock indications of more than 900 units become less frequent. In agreement with the high SRI is the high organic carbon content, which can reach values of up to 59 wt%. The type of organic matter ranges from "humic" to "mainly humic", thus pointing to a certain oil generation potential. Maceral analyses indicate that samples 5531 and 6030 ft are coals with a very small amount of liptinites. Samples 6580, 6980 and 7327 ft are liptinite-rich coaly

shales. The SOM is present in a favourable amount and habitat. Samples of depth 7830 ft onwards are coaly shales. No liptinites are observed and the SOM is present in a favourable amount and habitat.

Thus the samples of the upper part (5531 and 6030 ft) of the Easter View Coal Measures can be regarded as source rock for gas. With increasing depth the oil potential increases. This oil will show a distinct contribution of landplant matter (predominant resins). From sample 7830 ft onwards the oil will not show a landplant contribution due to the lack of liptinites. In this interval the liptinites - if present before - would have disappeared by the relatively high maturity ( $VR/E \pm 0.85$ ). In general the following can be said about the maturity of the Easter View Coal Measures: the conventional oil window is approached at a depth of ca. 6700 ft ( $VR/E = 0.62$ ), see figure 2.

However in this formation with liptinites, maturity for oil generation may have been reached at a lower  $VR/E$  level. At 9030 ft a  $VR/E$  value of 0.97 has been measured, meaning that the oil window is almost closed. The only partially conversion of the SOM and the "mainly humic" type of organic matter shows however that at total depth the sediments are not yet totally postmature for oil generation. The higher vitrinite reflectance values of 1.20 and 1.13 at depths of 7830 and 8030 ft are due to severe oxidation.

IV SUMMARY

The examined part of the Torquay Group contains no source rocks.

The Demons Bluff formation contains only marginal source rocks for gas.

The Boonah sandstone formation contains no source rocks.

The Easter View Coal measures contain excellent source rocks for gas. However a considerable oil potential consists additionally. From a depth of approximately 6000 ft this formation becomes mature and even at the total depth of 9843 ft the Easter View Coal Measures seem not to be totally postmature for oil generation.

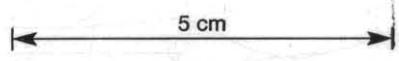
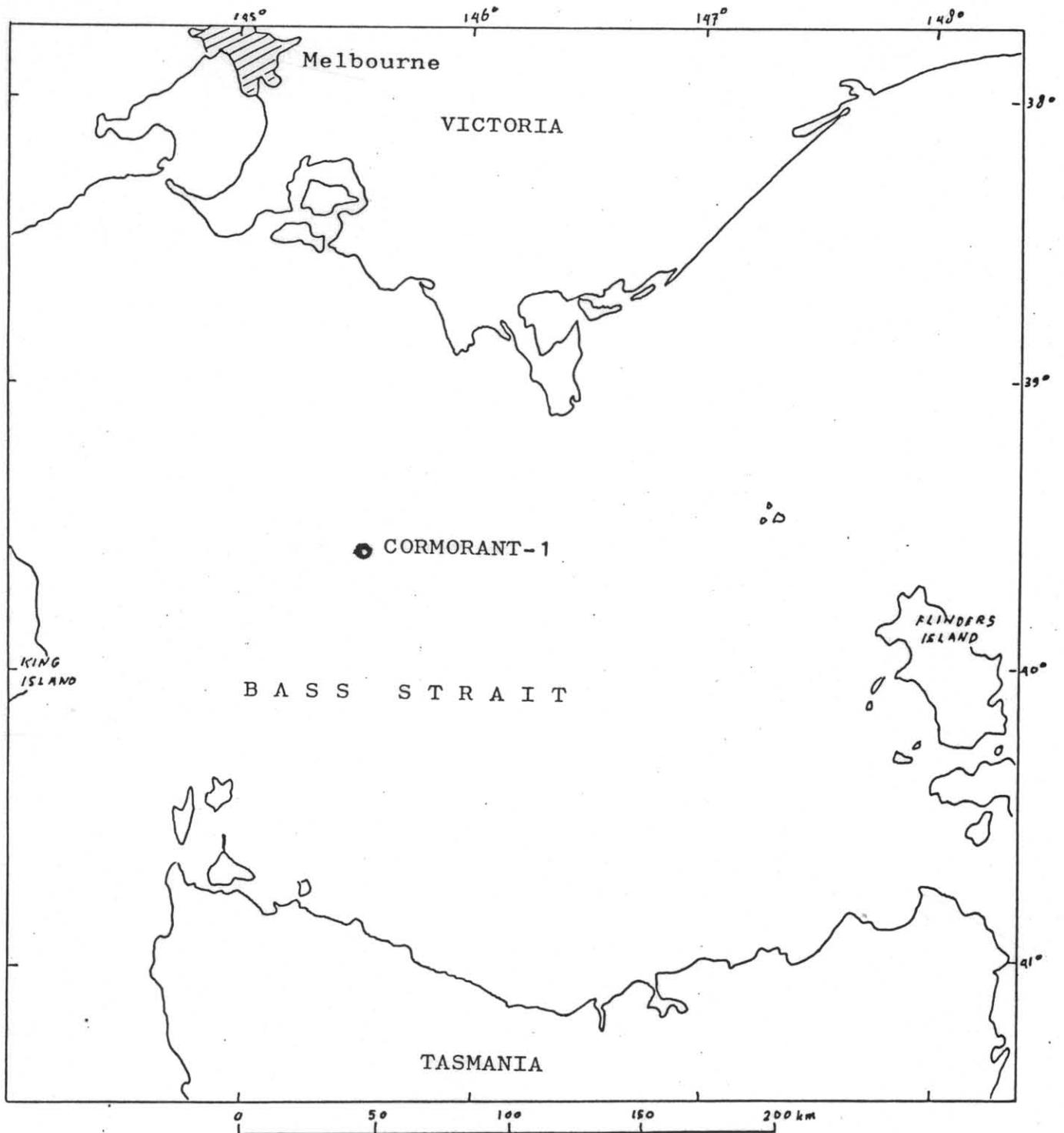
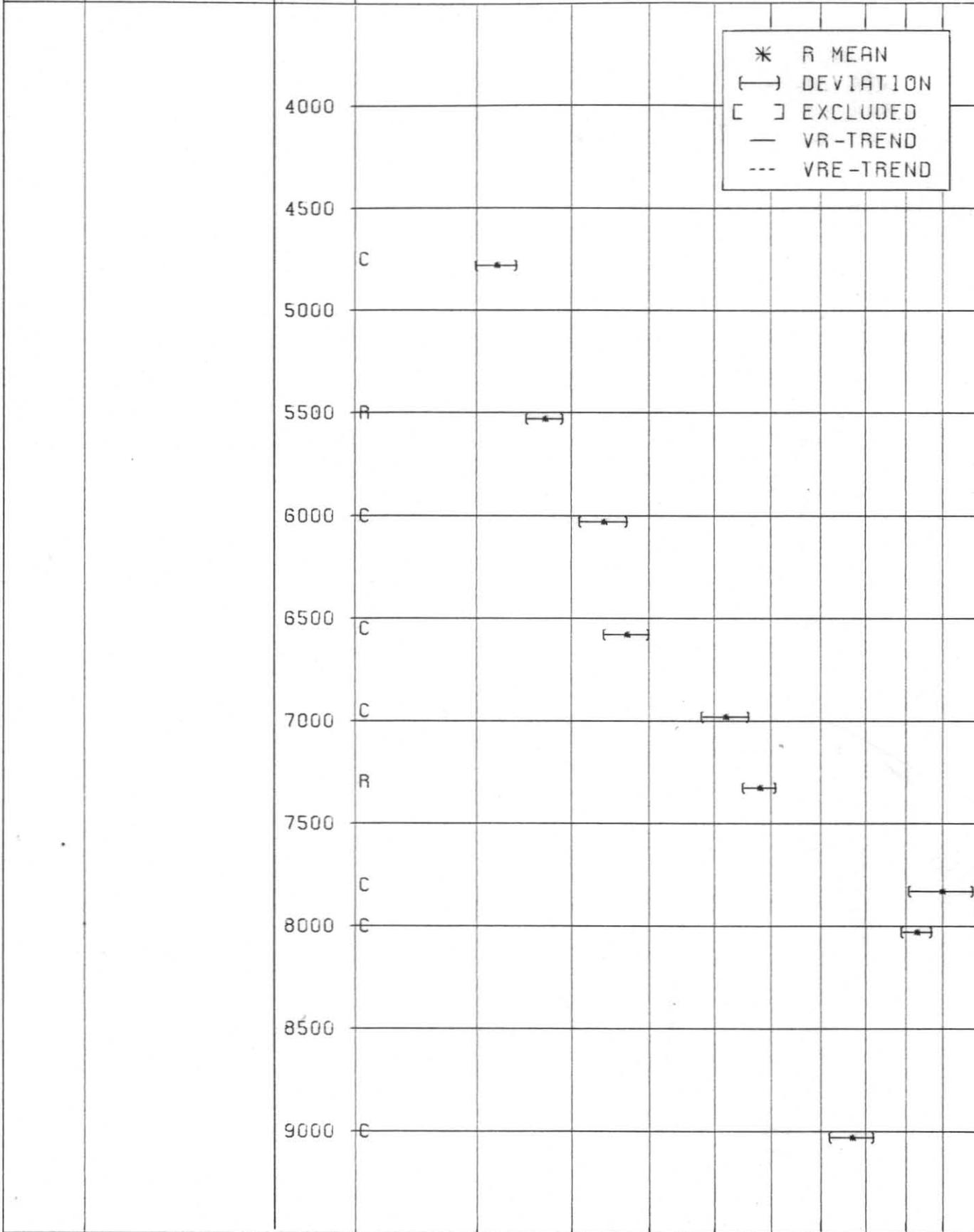


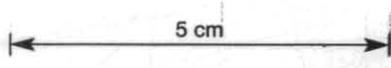
figure 1 Location map

AGE	FORMATION	DEPTH FEET BDF.	WELL : CORMORANT-1 COUNTRY : AUSTRALIA
-----	-----------	-----------------------	---



VR. (E) : 0.3      0.4      0.5      0.6      0.7      0.8      1.0

VITRINITE REFLECTANCE (OR EQUIVALENT) AS A FUNCTION OF DEPTH



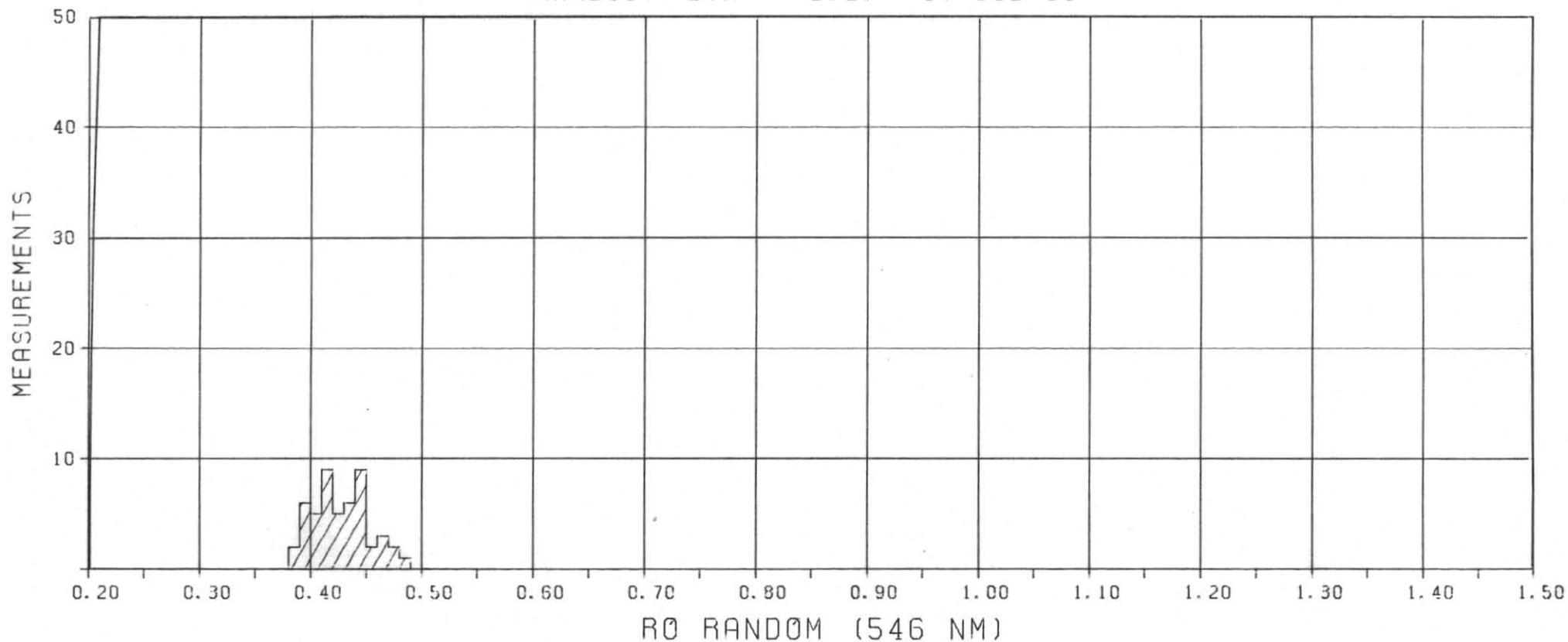
# VITRINITE REFLECTANCE

5 cm

COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 4780 FT  
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 0.42  
DEVIATION : 0.02  
MODE : MULTI  
MEASUREMENTS : 50

ANALIST : BTX D. D. : 07-JUL-81

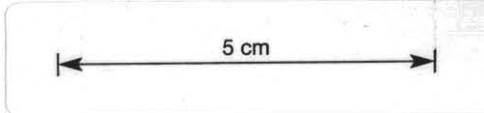


VITRINITE REFLECTANCE HISTOGRAM

Figure 3

339013

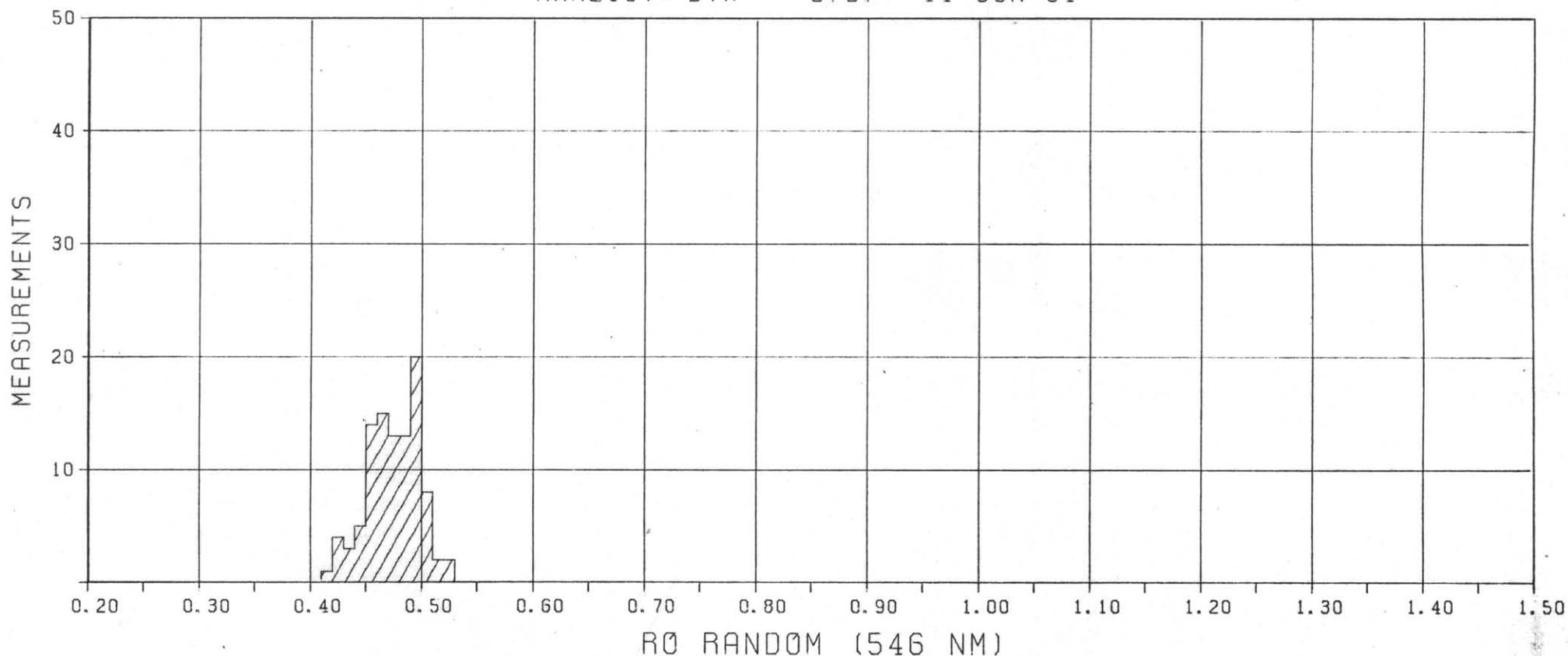
# VITRINITE REFLECTANCE



COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 5531 FT  
SAMPLE TYPE : CORE SAMPLE

MEAN : 0.47  
DEVIATION : 0.02  
MODE : 0.49  
MEASUREMENTS : 100

ANALYST : BTX D. D. : 11-JUN-81

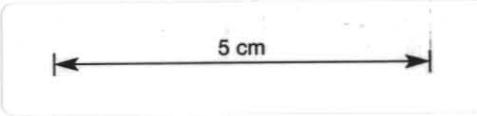


VITRINITE REFLECTANCE HISTOGRAM

figure 4

339014

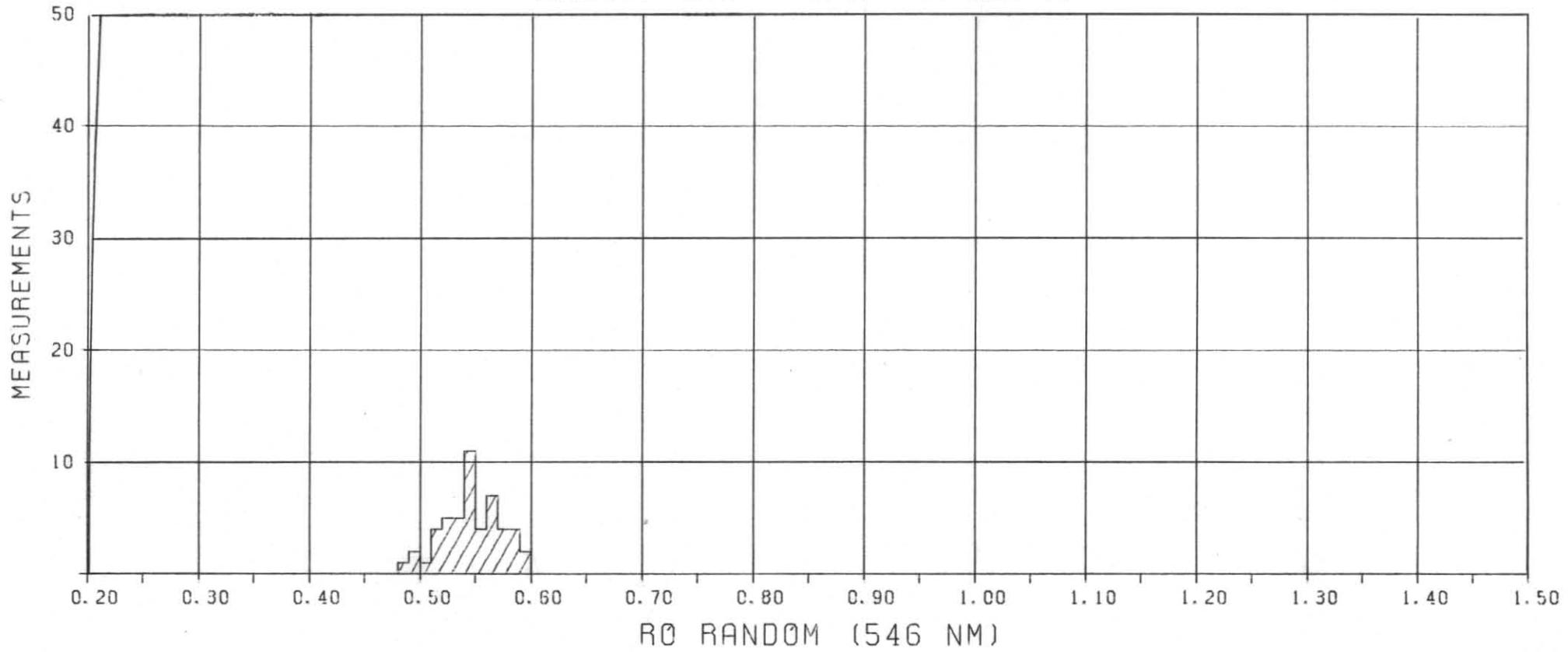
# VITRINITE REFLECTANCE



COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 6030 F1  
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 0.54  
DEVIATION : 0.03  
MODE : 0.54  
MEASUREMENTS : 50

ANALIST : BTX D. D. : 07-JUL-81



VITRINITE REFLECTANCE HISTOGRAM

figure 5

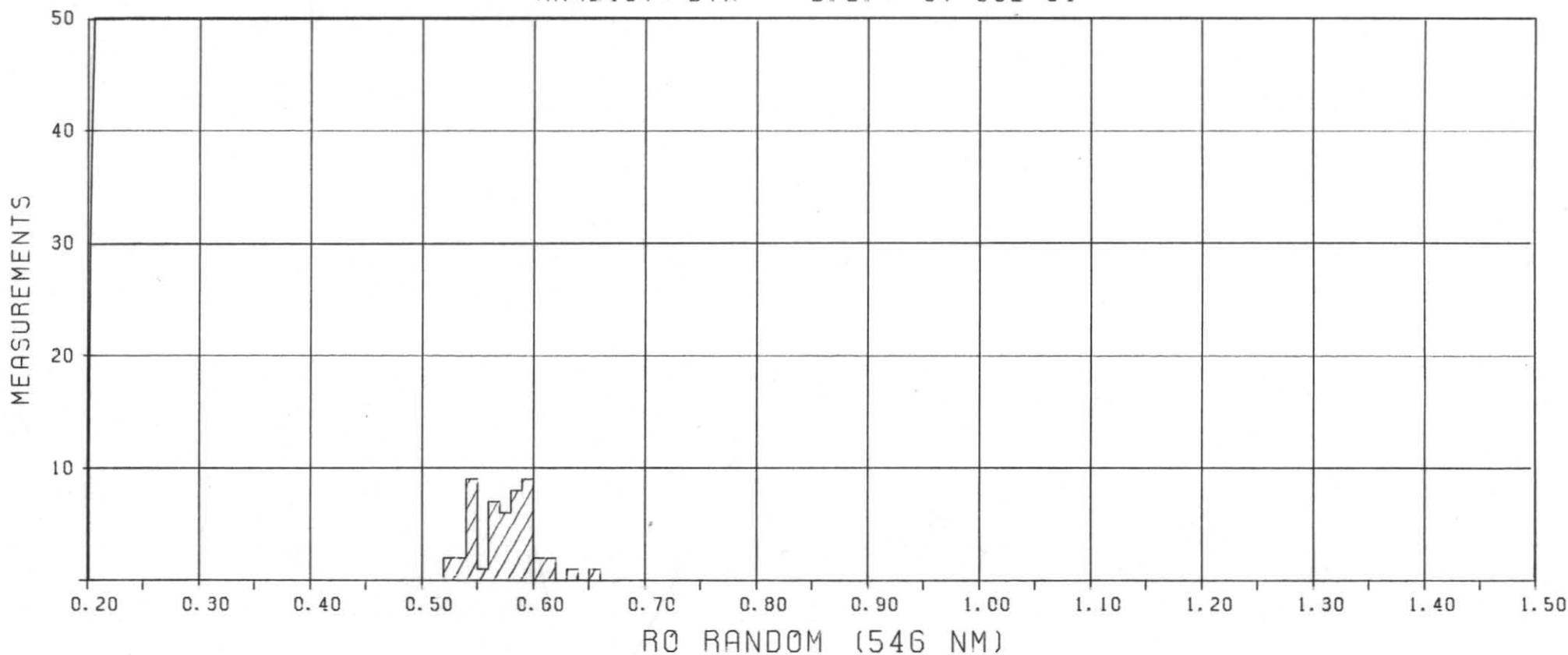
339015

# VITRINITE REFLECTANCE

5 cm

COUNTRY	: AUSTRALIA	MEAN	: 0.57
WELL/OUTCROP	: CORMORANT-1	DEVIATION	: 0.03
DEPTH/SAMPLE NR.	: 6580 FT	MODE	: MULTI
SAMPLE TYPE	: CUTTING SAMPLE	MEASUREMENTS:	50

ANALYST: BTX D. D. 07-JUL-81



VITRINITE REFLECTANCE HISTOGRAM

figure 6

339016

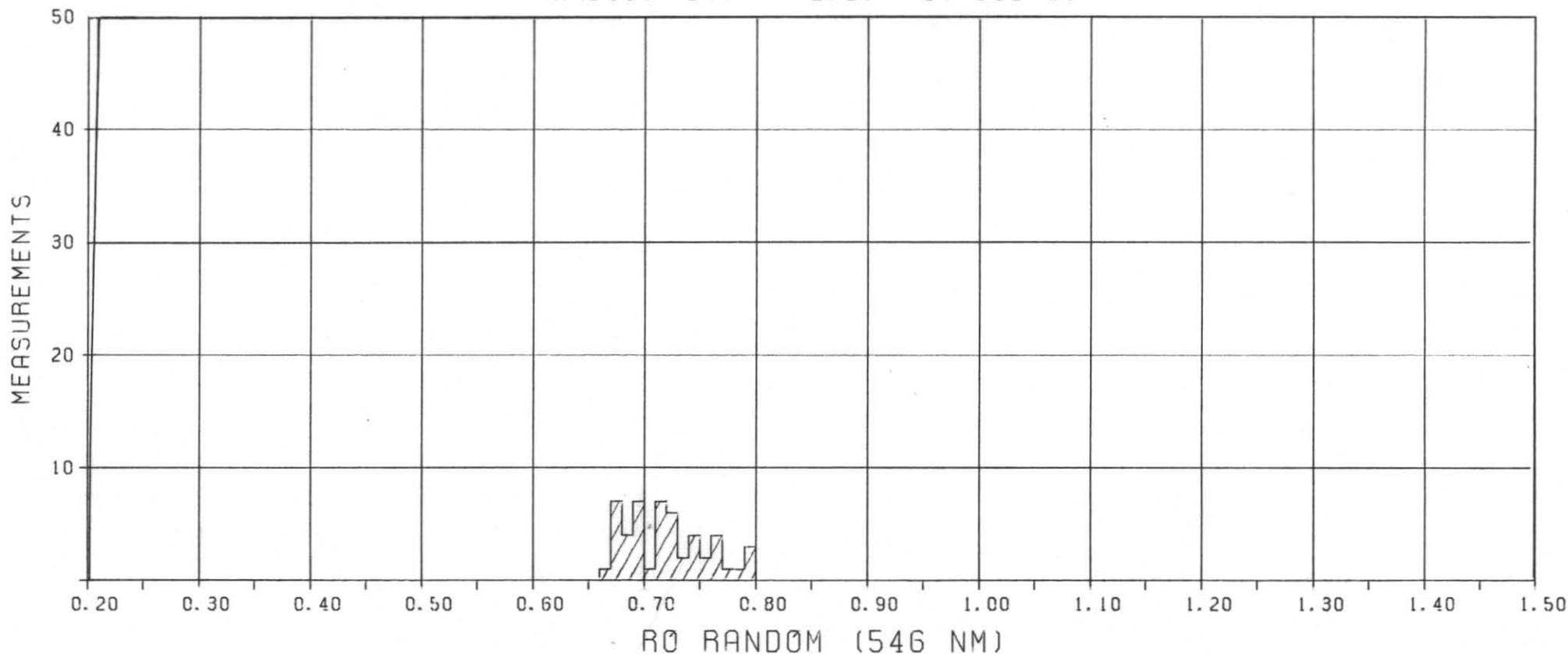
# VITRINITE REFLECTANCE

5 cm

COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 6980 FT  
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 0.72  
DEVIATION : 0.04  
MODE : MULTI  
MEASUREMENTS : 50

ANALIST : BTX D. D. : 07-JUL-81

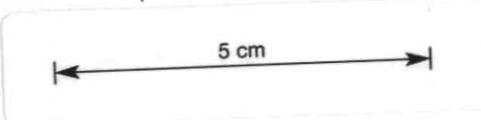


VITRINITE REFLECTANCE HISTOGRAM

figure 7

339017

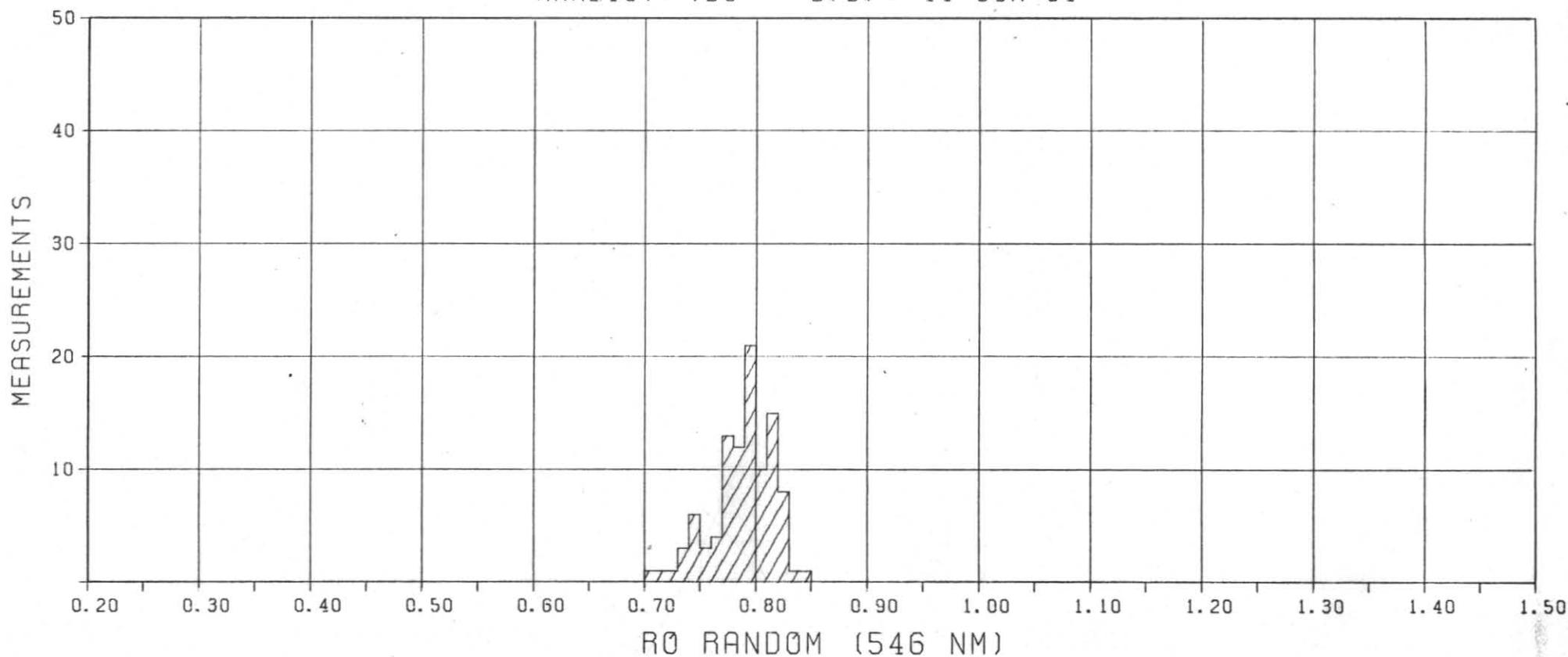
# VITRINITE REFLECTANCE



COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 7327 FT  
SAMPLE TYPE : CORE SAMPLE

MEAN : 0.78  
DEVIATION : 0.03  
MODE : 0.79  
MEASUREMENTS : 100

ANALYST : VBS D. D. : 11-JUN-81



VITRINITE REFLECTANCE HISTOGRAM

figure 8

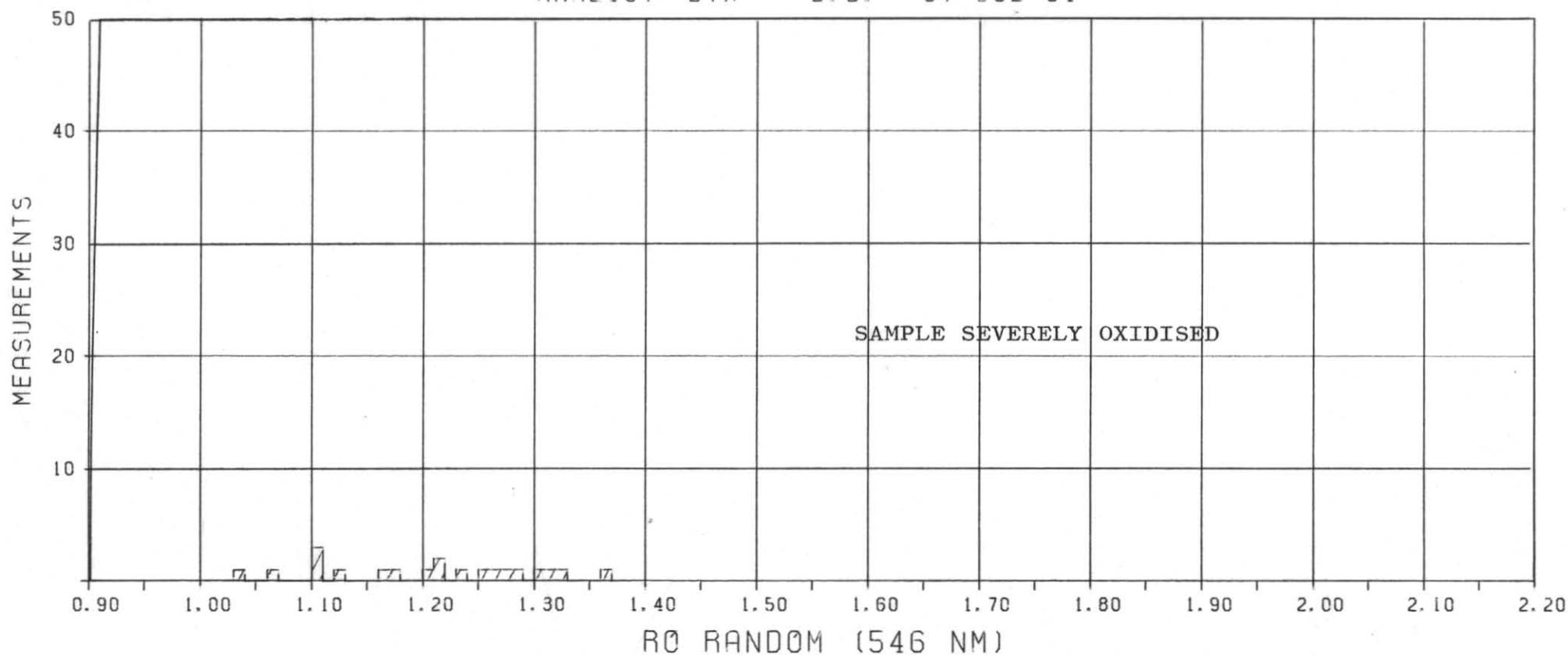
339018

# VITRINITE REFLECTANCE

5 cm

COUNTRY	: AUSTRALIA	MEAN	: 1.20
WELL/OUTCROP	: CORMORANT-1	DEVIATION	: 0.09
DEPTH/SAMPLE NR.	: 7830 FT	MODE	: 1.10
SAMPLE TYPE	: CUTTING SAMPLE	MEASUREMENTS:	20

ANALYST: BTX      D. D. : 07-JUL -81

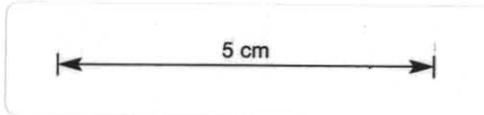


VITRINITE REFLECTANCE HISTOGRAM

figure 9

339019

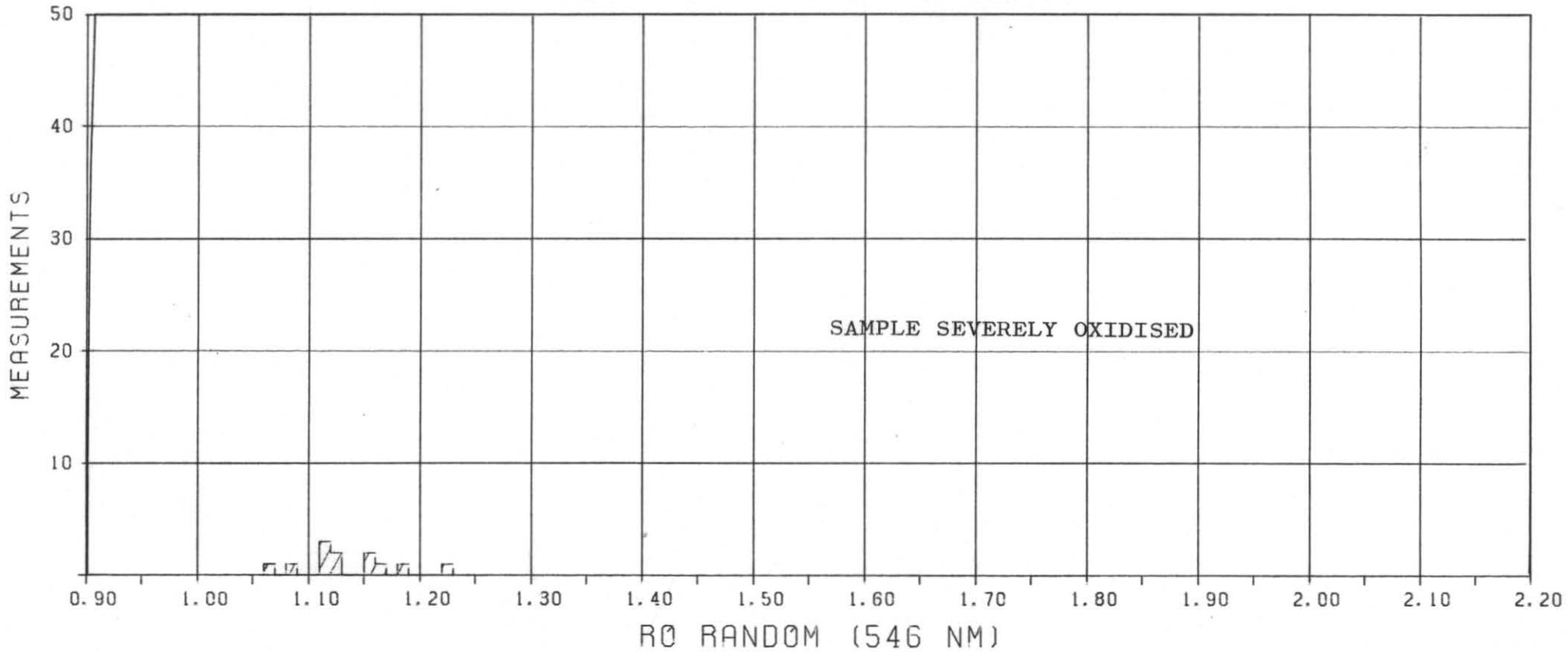
# VITRINITE REFLECTANCE



COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 8030 FT  
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 1.13  
DEVIATION : 0.04  
MODE : 1.11  
MEASUREMENTS : 12

ANALIST : BTX D. D. : 07-JUL-81



VITRINITE REFLECTANCE HISTOGRAM

figure 10

339020

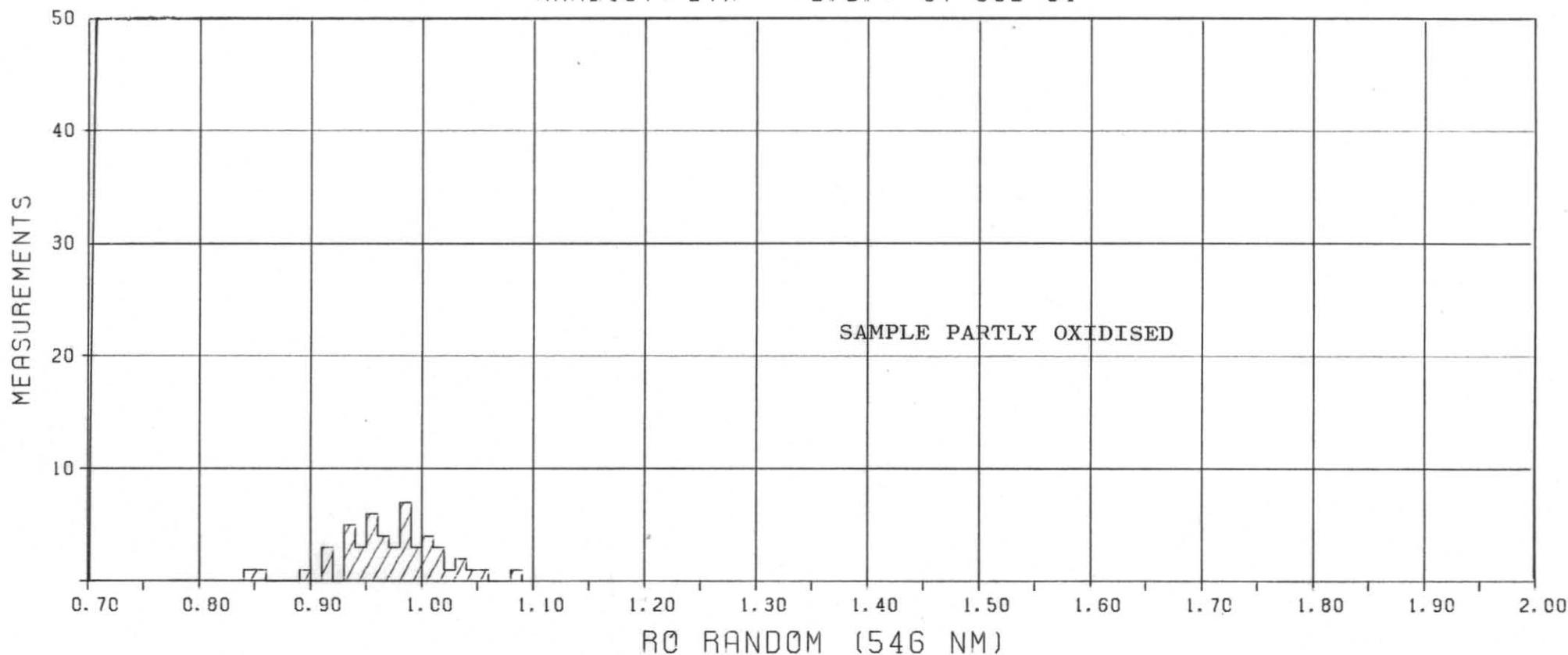
# VITRINITE REFLECTANCE

5 cm

COUNTRY : AUSTRALIA  
WELL/OUTCROP : CORMORANT-1  
DEPTH/SAMPLE NR. : 9030 FT  
SAMPLE TYPE : CUTTING SAMPLE

MEAN : 0.97  
DEVIATION : 0.05  
MODE : 0.98  
MEASUREMENTS : 50

ANALIST : BTX D. D. : 07-JUL-81



VITRINITE REFLECTANCE HISTOGRAM

figure 11

339021

TABLE I (PART 1)

WELL: CORMORANT-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
F		BEFORE EXTR.	AFTER EXTR.		%W
2997	R	105	10		-
3000	C	10	-		-
3030	C	35	5		-
3080	C	5	-		-
3130	C	5	-		-
3180	C	10	-		-
3230	C	5	-		-
3280	C	20	-		-
3330	C	10	-		-
3380	C	15	-		-
3430	C	25	-		-
3490	C	20	-		-
3530	C	35	35		-
3580	C	25	-		-
3630	C	55	65		-
3680	C	110	100	H	4.0
3730	C	40	50		-
3780	C	45	55		-
3815	R	30	35		-
3818	R	50	75		-
3880	C	35	45		-
3930	C	110	95		-
3980	C	40	55		-
4030	C	35	50		-
4080	C	15	-		-
4130	C	25	-		-
4180	C	20	-		-
4230	C	10	-		-
4330	C	15	-		-
4380	C	20	-		-

TABLE I (PART 2)

WELL: CORMORANT-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
F		BEFORE EXTR.	AFTER EXTR.		%W
4430	C	20	-		-
4480	C	10	-		-
4530	C	20	-		-
4580	C	15	-		-
4630	C	10	-		-
4680	C	20	-		-
4730	C	> 900	> 900		-
4780	C	400	400	MH	31.3
4830	C	425	445		-
4880	C	190	200		-
4930	C	10	-		-
4980	C	240	275		-
5030	C	700	660		-
5080	C	550	520		-
5130	C	395	405		-
5180	C	410	425		-
5230	C	150	175		-
5280	C	365	330		-
5330	C	335	370		-
5380	C	> 900	> 900		-
5430	C	> 900	> 900		-
5480	C	> 900	> 900		-
5531	R	> 900	> 900		-
5540	C	> 900	> 900		-
5580	C	> 900	> 900		-
5630	C	> 900	> 900		-
5680	C	> 900	> 900		-
5732	C	> 900	> 900		-
5780	C	> 900	> 900		-
5830	C	> 900	> 900		-

TABLE I (PART 3)

WELL: CORMORANT-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION		SOURCE ROCK INDICATION		TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT  %W
		BEFORE EXTR.	AFTER EXTR.	BEFORE EXTR.	AFTER EXTR.		
5880	C	>	900	>	900		-
5930	C	>	900	>	900		-
5980	C	>	900	>	900		-
6030	C	>	900	>	900	H	58.3
6030	C	>	900	>	900	H	59.5
6080	C	>	900	>	900		-
6130	C	>	900	>	900		-
6180	C	>	900	>	900		-
6230	C	>	900	>	900		-
6280	C	>	900	>	900		-
6330	C	>	900	>	900		-
6380	C	>	900	>	900		-
6430	C	>	900	>	900		-
6480	C	>	900	>	900		-
6540	C		15		-		-
6548	R		70		60		-
6580	C	>	900	>	900	H	21.5
6630	C	>	900	>	900		-
6680	C	>	900	>	900		-
6730	C	>	900	>	900		-
6780	C	>	900	>	900		-
6830	C	>	900	>	900		-
6880	C	>	900	>	900		-
6930	C	>	900	>	900		-
6980	C	>	900	>	900	MH	20.8
7030	C	>	900	>	900		-
7080	C	>	900	>	900		-
7130	C	>	900	>	900		-
7190	C	>	900	>	900		-
7230	C	>	900	>	900		-

TABLE I (PART 4)

WELL: CORMORANT-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
F		BEFORE EXTR.	AFTER EXTR.		%W
7280	C	> 900	> 900		-
7327	R	> 900	> 900		-
7330	C	> 900	> 900		-
7380	C	> 900	> 900		-
7430	C	> 900	> 900		-
7480	C	> 900	> 900		-
7530	C	435	300		-
7580	C	> 900	510		-
7630	C	745	745		-
7680	C	> 900	> 900		-
7730	C	> 900	> 900		-
7780	C	530	430		-
7830	C	315	310	MH	6.3
7880	C	220	215		-
7930	C	> 900	> 900		-
7980	C	175	165		-
8030	C	400	400	MH	17.3
8080	C	340	260		-
8130	C	300	275		-
8180	C	225	220		-
8230	C	30	25		-
8280	C	50	35		-
8330	C	20	-		-
8380	C	305	275		-
8430	C	65	70		-
8480	C	85	85		-
8530	C	30	35		-
8580	C	240	110	H	12.3
8630	C	145	150		-
8690	R	95	75		-

TABLE I (PART 5)

WELL: CORMORANT-1

DEPTH	TYPE OF SAMPLE	SOURCE ROCK INDICATION	SOURCE ROCK INDICATION	TYPE OF ORGANIC MATTER	ORGANIC CARBON CONTENT
F		BEFORE EXTR.	AFTER EXTR.		%W
8700	C	180	180		-
8730	C	145	135		-
8780	C	70	65		-
8830	C	60	75		-
8880	C	225	210		-
8900	C	425	440		-
8930	C	540	495		-
9030	C	> 900	> 900	MH/H	19.3
9080	C	> 900	> 900		-
9126	R	250	230		-
9130	C	470	425		-
9180	C	320	345		-
9230	C	> 900	> 900		-
9280	C	595	495		-
9330	C	400	405		-
9380	C	135	155		-
9430	C	100	120		-
9480	C	220	195		-
9530	C	70	55		-
9580	C	105	70		-
9630	C	470	395	MH	6.8
9680	C	135	145		-
9730	C	205	220		-
9780	C	95	85		-
9830	C	140	115		-

TYPE OF SAMPLE C = CUTTINGS, R = CORE, S = SIDEWALL SAMPLE

CONTAMINATION : W = WALNUT FRAGMENTS OR SOME SIMILAR PRODUCT, E = CELLOPHANE SHREDS, F = FIBRES, P = PLASTIC OR PAINT AND C = CONTAMINATED BUT KIND NOT SPECIFIED

A DASH (-) INDICATES TEST NOT MADE, ASTERISKS INDICATE THE ORGANIC CARBON CONTENT IS THE AVERAGE FOR THE SAMPLES CONCERNED

TABLE II

Maceral description of 13 samples from well Cormorant-1

core 2997 ft:

- rare SOM, vitrinite, liptodetrinite and exsudatinitite;
- sample partly oxidised.

cuttings 3680 ft:

- common SOM;
- few vitrinite, sporinite, resinite and liptodetrinite;
- rare cutinite, exsudatinitite, fusinite, suberinitite and solid hydrocarbons;
- sample partly oxidised.

cuttings 4780 ft:

- abundant vitrinite;
- common resinite and liptodetrinite;
- few SOM, sporinite and suberinitite;
- rare exsudatinitite, sclerotinitite, fusinite and cutinite;
- vitrinite shows oxidation features and grades into SOM, associated with pyrite;
- few severely oxidised coal particles.

core 5531 ft:

- abundant vitrinite;
- few liptodetrinite;
- rare sporinite, resinite, exsudatinitite, sclerotinitite and fusinite.

cuttings 6030 ft:

- abundant vitrinite;
- common liptodetrinite;
- few sporinite, resinite, fusinite and suberinitite;
- rare SOM, cutinite, exsudatinitite, and sclerotinitite.

TABLE II (continuation)

## cuttings 6580 ft:

- abundant vitrinite;
- common SOM, sporinite, resinite, liptodetrinite and micrinite
- few cutinite and fusinite;
- rare exsudatinite, sclerotinite, suberinite and solid hydrocarbons;
- initial conversion SOM;
- sample slightly oxidised;
- vitrinite shows oxidation features;
- few oxidised coal particles.

## cuttings 6980 ft:

- common SOM, vitrinite and micrinite;
- few sporinite, resinite, liptodetrinite, exsudatinite and fusinite;
- rare cutinite and sclerotinite;
- vitrinite shows oxidation features and grades into SOM;
- common oxidised coal particles.

## core 7327 ft:

- abundant SOM and vitrinite;
- common resinite, liptodetrinite and micrinite;
- few sporinite, cutinite and exsudatinite;
- SOM partly converted;
- vitrinite grades into SOM;
- sample slightly oxidised.

## cuttings 7830 ft:

- common SOM, vitrinite and micrinite;
- rare sporinite, liptodetrinite, exsudatinite and fusinite;
- vitrinite grades into SOM associated with pyrite;
- SOM partly converted;
- most particles severely oxidised.

TABLE II (continuation)

## cuttings 8030 ft:

- common SOM, vitrinite and micrinite;
- rare sporinite, liptodetrinite, exsudatinite and fusinite;
- vitrinite shows oxidation features;
- vitrinite grades into SOM, associated with pyrite;
- SOM partly converted;
- most particles severely oxidised;
- caving observed.

## cuttings 8580 ft:

- common SOM, vitrinite and micrinite;
- rare sporinite, liptodetrinite, exsudatinite and fusinite;
- rare sclerotinite;
- vitrinite shows oxidation features;
- vitrinite grades into SOM, associated with pyrite;
- SOM partly converted;
- most particles severely oxidised;
- some caving.

## cuttings 9030 ft:

- common SOM, vitrinite and micrinite;
- few exsudatinite;
- rare fusinite;
- vitrinite shows oxidation features;
- vitrinite grades into SOM, associated with pyrite;
- SOM partly converted;
- most particles severely oxidised.

## cuttings 9630 ft:

- common SOM and micrinite;
- few vitrinite;
- rare exsudatinite and fusinite;
- vitrinite shows oxidation features;
- vitrinite grades into SOM, associated with pyrite;
- SOM partly converted;
- most particles severely oxidised.

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