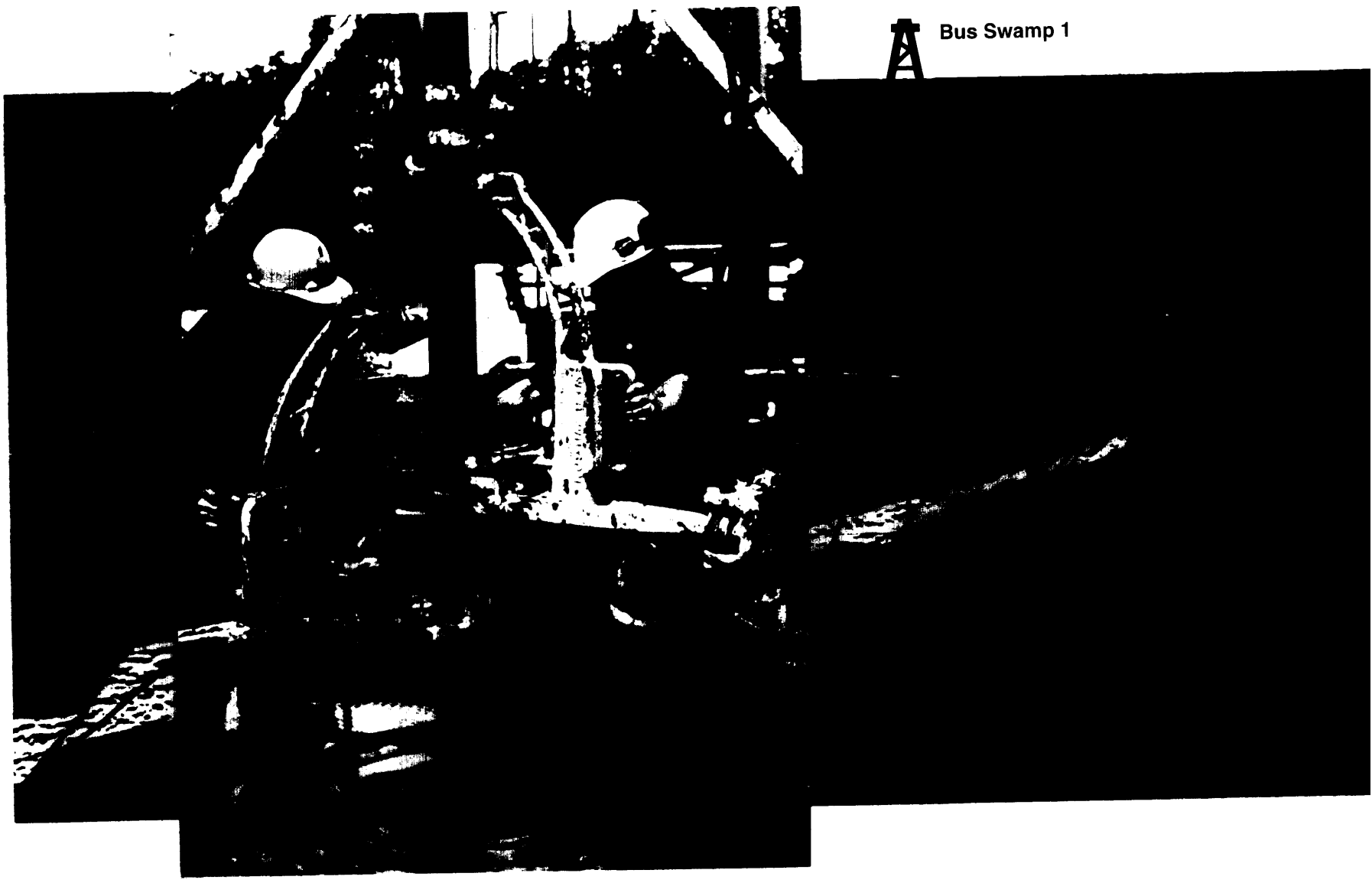
Bus Swamp 1

Well Completion Report



Geological Survey of Victoria
Basin Studies

1993

VOL. I: TEXT & APPENDICES

Department of Energy and Mi

EXECUTIVE SUMMARY

Bus Swamp 1 was drilled as part of the Geological Survey of Victoria's (GSV) stratigraphic drilling programme in the Otway Basin. This programme is an important component of a major study being carried out by the Basin Studies Section of the GSV. The study involves a systematic review of all relevant data on the Otway Basin, including information held by government agencies and petroleum exploration companies. The study will increase the understanding of the evolution of the Otway Basin and will provide a better delineation of the source and reservoir rocks in the basin. It will provide an up to date regional framework for use by petroleum explorers in developing hydrocarbon plays.

The National Geoscience Mapping Accord's (NGMA) Otway Basin Project forms part of this study. The NGMA Project involves seismic interpretation of the onshore Otway Basin in order to improve knowledge of the tectonic events that resulted in basin development and evolution. The project involves contributions by Australian Geological Survey Organisation, Mines and Energy-South Australia, Victorian Institute of Earth and Planetary Sciences and GSV.

Bus Swamp 1 was drilled near the northern margin of the Penola Trough, part of the Late Jurassic - Early Cretaceous rift system which initiated the Otway Basin, in order to aid the seismic interpretation of the NGMA Project.

The well was drilled by the Rural Water Corporation Drilling Unit for the Geological Survey of Victoria, a division of the Victorian Department of Energy and Minerals. Drilling began on 19 November, 1992 and reached a total depth of 1850.5 m on 17 December, 1992.

Four conventional cores were recovered, in addition to a full suite of industry standard wireline logs being run and a velocity survey carried out. The target Otway Group sediments, including Eumeralla Formation, Crayfish Subgroup and Casterton Formation, were intersected, in addition to basement.

The well was monitored using a gas chromatograph and hot wire total gas detector with peak gas readings of 23.8 units and 21.8 units being detected. Hydrocarbon fluorescence was also noted at several depths. Bus Swamp 1 was plugged and abandoned as a dry hole following logging.

Bus Swamp 1 could not have been undertaken without financial support from the following organisations:

SANTOS (Formerly AGL Petroleum)
BHP Petroleum
Gas and Fuel Exploration N.L.
Minora Resources
Pan Pacific Petroleum
Ampolex
Cultus Petroleum
Lakes Oil Ltd
Oil Company of Australia
SAGASCO Resources

AGSO and SADME provided additional palynological and geochemical analyses. The contributions by all these organisations are gratefully acknowledged.

The GSV is pleased with the acquired data and considers that Bus Swamp 1 was successful in meeting the project's objectives, and believe that the results will stimulate increased exploration in this area of the Otway Basin.

B Simons 11/3/94

BRUCE SIMONS
Manager, Basin Studies

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APPENDIX 8

GEOCHEMISTRY ANALYSIS

AMDEL
CORE
SERVICES

13 April 1993

Deparment of Energy and Minerals
Geological Survey of Victoria
Private Bag No 1
East Melbourne 3002

Attention: Cliff Menhennitt

REPORT: HH/2223

CLIENT REFERENCE:	022514
MATERIAL:	Rock Samples
LOCALITY:	Bus Swamp-1
WORK REQUIRED:	Source Rock Analysis

Please direct technical enquiries regarding this work to the signatory below under whose supervision the work was carried out.

BRIAN L WATSON
Laboratory Supervisor-Geochemistry
on behalf of Amdel Core Services Pty Ltd

ANTHONY M DRAKE
Laboratory Supervisor
Special Core Analysis

Adelaide Office: P.O. Box 109, Eastwood, SA 5063 Australia.
Telephone: (08) 372 2834 Facsimile: (08) 372 2861
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
Telephone: (08) 379 9888 Facsimile: (08) 379 9288

Amdel Core Services Pty Limited
(Incorporated in South Australia)
ACN: 008 273 005

1. INTRODUCTION

A total of twenty-two (22) samples were received for TOC analysis, Rock-Eval pyrolysis, vitrinite reflectance, helium injection porosity and ambient air permeability analysis along with preparation of two thin sections. This report is a formal presentation of results which were forwarded by facsimile as they became available.

2. ANALYTICAL PROCEDURES

2.1 Sample Preparation

Samples for TOC/Rock-Eval analysis (as received) were ground in a Siebtechnik mill for 20-30 seconds.

2.2 Total Organic Carbon (TOC)

Total organic carbon was determined by digestion of a known weight (approximately 0.2 g) of powdered rock in HCl to remove carbonates, followed by combustion in oxygen in the induction furnace of a Leco WR-12 Carbon Determinator and measurement of the resultant CO_2 by infra-red detection.

2.3 Rock-Eval Pyrolysis

A 100 mg portion of powdered rock was analysed by the Rock-Eval pyrolysis technique (Girdel IFP-Fina Mark 2 instrument; operating mode, Cycle 1).

2.4 Organic Petrology

Representative portions of each sample (crushed to -14+35 BSS mesh) were obtained with a sample splitter and then mounted in cold setting Glasscraft resin using a 2.5 cm diameter mould. Each block was ground flat using diamond impregnated laps and carborundum paper. The surface was then polished with aluminium oxide and finally magnesium oxide.

Reflectance measurements were made with a Leitz MPV1.1 microphotometer fitted to a Leitz Ortholux microscope and calibrated against synthetic standards. All measurements were taken using oil immersion (n = 1.518) and incident monochromatic light (wavelength 546 nm) at a temperature of 23±1°C. Fluorescence observations were made on the same microscope utilizing a 3 mm BG3 excitation filter, a TK400 dichroic mirror and a K510 suppression filter.

2.5 Warm Solvent Extraction and Humidity Drying

The samples undergoing porosity and permeability analysis were extracted using a chloroform/methanol azeotropic mixture to leach residual pore fluids. Prior to porosity and air permeability measurements, samples were dried at 50°C and 50% relative humidity. 50% relative humidity was achieved using a saturated solution of sodium nitrite.

2.6 Permeability to air

Air permeability was determined on the clean and dry plug samples. The samples were firstly placed in a Hassler cell with a confining pressure of 250 psi (1720 kPa). The confining pressure was used to prevent bypassing of air around the samples when the measurement was made. To determine permeability a known air pressure was applied to the upstream face of the sample, creating a flow of air through the core plug. Permeability for the samples was calculated using Darcy's Law through knowledge of the upstream pressure, flow rate, viscosity of air and the samples' dimensions.

2.7 Helium injection porosity

The porosity of the clean dry core plugs was determined as follows. The plugs were first placed in a sealed matrix cup. Helium held at 100 psi reference pressure was then introduced to the cup. From the resultant pressure change the unknown grain volume was calculated using Boyle's Law (ie, $P_1V_1 = P_2V_2$). The bulk volume of the sample is determined by mercury immersion. From the grain volume and the bulk volume porosity can be calculated (ie porosity = (Bulk Vol - Grain Vol)/Bulk Volume)).

3. RESULTS

TOC and Rock-Eval data are listed in Table 1. Figure 1 is a plot of T_{max} versus Hydrogen Index illustrating kerogen Type and maturity. Table 2 is a summary of the vitrinite reflectance measurements which are presented along with histograms in Appendix 1, while Figure 2 is a plot of measured vitrinite reflectance versus depth. Porosity and permeability data is presented in Table 3.

4. INTERPRETATION

4.1 Maturity

Reliable measured vitrinite reflectance values (Table 2, Figure 2) range from 0.39-0.60% over the section studied and indicate that the samples are marginally mature to mature for the generation of liquid hydrocarbons. Oil generation from thermally labile exinites (resinite, bituminite and suberinite) commences at VR = 0.45%. The maturity versus depth profile indicates that this maturity is reached at approximately 1200 metres depth in this location. Oil generation from the less thermally labile exinites (cutinite, sporinite, etc) commences at higher maturities (VR >0.7%). Extrapolation of the available data indicates that these maturities should be reached in the sedimentary interval below approximately 2000 metres depth. Rock-Eval T_{max} values correspond well with the measured vitrinite reflectance values, suggesting a maturity range of $VR_{EQUIV} \approx 0.40$-0.60% (Table 1, Figure 1).

Significant gas generation commences at a maturity level of approximately VR = 0.6%. Therefore, measured vitrinite reflectance data suggests that the sediments in Bus Swamp-1 below approximately 1790 metres are sufficiently mature for such gas generation.

A high production index (P.I. >0.2; Table 1) suggests the presence of migrated hydrocarbons in the samples at depths 830-835 and 1406 metres.

4.2 Source Richness

Both organic richness and source richness range from poor to fair in the samples studied (TOC = 0.18-2.19%, $S_1 + S_2$ = 0.45-2.65 kg of hydrocarbons/tonne; Table 1). The most organic and source rich samples occur in the interval 1710 - 1810 metres (TOC = 1.01-2.19%, $S_1 + S_2$ = 1.88-2.65 kg of hydrocarbons/tonne; Table 1).

4.3 Kerogen Type and Source Quality

Hydrogen Index and T_{max} values (Table 1, Figure 1) indicate that these samples contain organic matter which has a bulk composition of Type II/III to Type IV kerogen. The better quality samples containing organic matter with the bulk composition of Type II/III to Type III kerogen occur in the interval 1585 - 1810 metres.

TABLE 1

AMDEL CORE SERVICES

Rock-Eval Pyrolysis

03/08/93

Client: South Australian and Victorian Dept.of Minerals and Energy

Well: Bus Swamp-1

Depth (m)	T Max	S1	S2	S3	S1+S2	PI	S2/S3	PC	TOC	HI	OI
465	439	0.01	0.44	0.29	0.45	0.02	1.51	0.03	0.88	50	32
756									0.18		
830-835	402	0.17	0.41	0.59	0.58	0.29	0.69	0.04	1.79	22	32
982									0.19		
1105	428	0.02	0.43	0.33	0.45	0.05	1.30	0.03	0.98	43	33
1190	434	0.05	0.49	0.41	0.54	0.09	1.19	0.04	0.89	55	46
1325									0.33		
1406	303	0.25	0.50	0.27	0.75	0.34	1.85	0.06	0.86	58	31
1585	438	0.11	0.83	2.22	0.94	0.12	0.37	0.07	0.95	87	233
1710	436	0.16	1.97	2.32	2.13	0.08	0.84	0.17	1.48	133	156
1790	439	0.11	1.77	0.66	1.88	0.06	2.68	0.15	1.01	175	65
1803	437	0.34	2.31	1.47	2.65	0.13	1.57	0.22	1.61	143	91
1805-1810	437	0.15	2.29	1.48	2.44	0.06	1.54	0.20	2.19	104	67

TABLE 2

SUMMARY OF VITRINITE REFLECTANCE MEASUREMENTS, BUS SWAMP-1

Depth (m)	Mean Maximum Reflectance (%)	Standard Deviation	Range	Number of Determinations
465	0.40	0.05	0.31 - 0.47	8
756	0.39	0.05	0.31 - 0.48	12
830 - 835	0.41	0.05	0.36 - 0.47	6
862	0.40	0.03	0.36 - 0.46	22
913	0.40	0.03	0.33 - 0.45	14
982	0.43	0.02	0.41 - 0.46	3
1105	0.41	0.02	0.39 - 0.43	2
1190	0.45	0.05	0.39 - 0.54	14
1406	0.63 *	0.03	0.59 - 0.67	4
1509 - 15	0.49	0.10	0.39 - 0.64	6
1585	0.47	0.03	0.40 - 0.55	26
1709	0.55	0.06	0.46 - 0.65	25
1790	0.60	0.04	0.53 - 0.66	12
1805 - 10	0.60	0.04	0.50 - 0.66	15
1815	0.60	0.04	0.54 - 0.66	29

* Influenced by re-worked vitrinite

HYDROGEN INDEX vs T max

Client :South Australian and Victorian Dept.of Minerals and Energy
Location :Bus Swamp-1

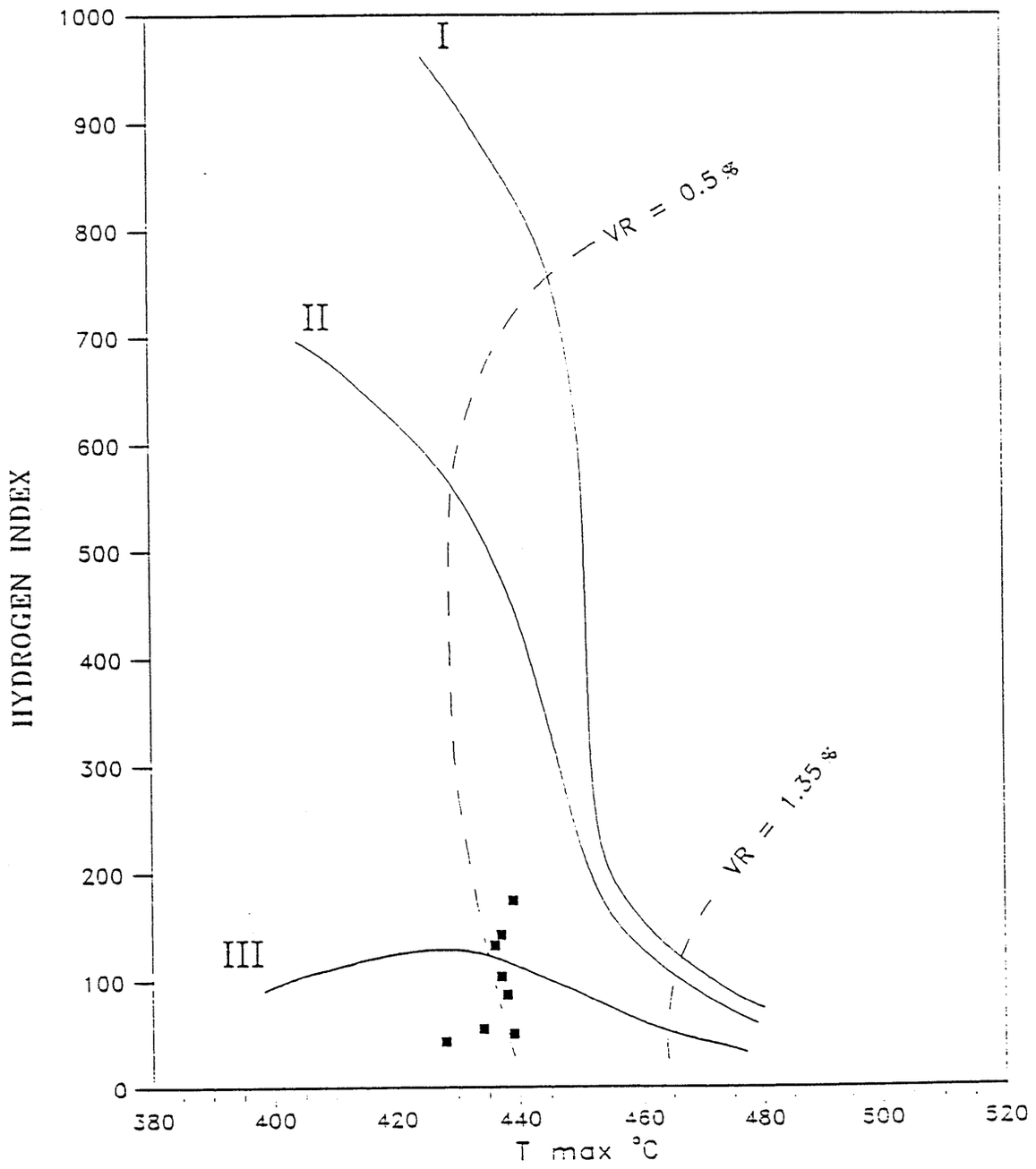
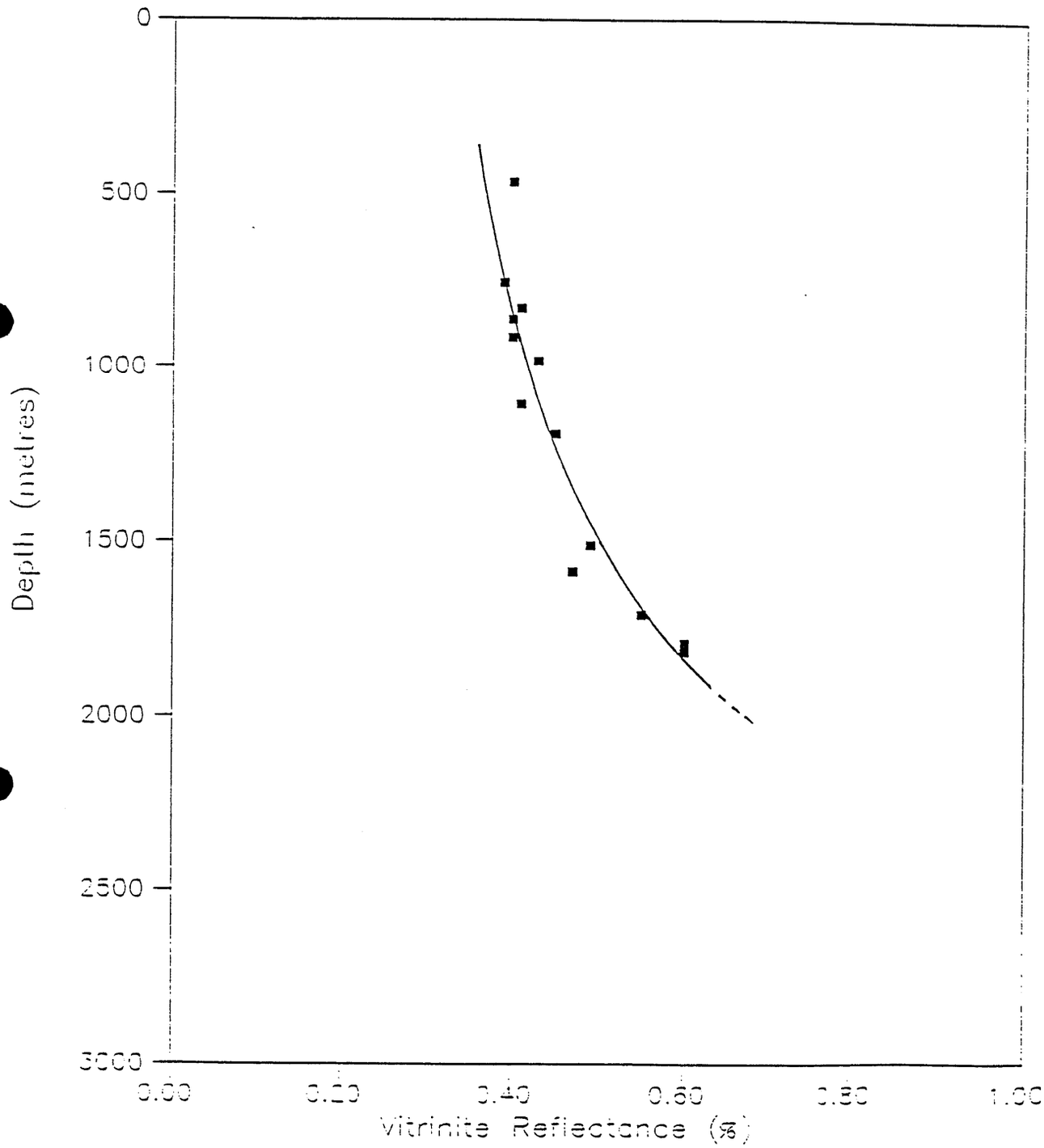


FIGURE 2

VITRINITE REFLECTANCE VERSUS DEPTH
BUS SWAMP-1



APPENDIX 1

HISTOGRAM PLOTS OF VITRINITE REFLECTANCE DATA

BUS SWAMP-1

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 465 m

Sorted List

0.31
0.36
0.36
0.40
0.41
0.42
0.44
0.47

Number of values= 8

Mean of values 0.40
Standard Deviation 0.05

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

31-33	*
34-36	**
37-39	
40-42	***
43-45	*
46-48	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 756 m

Sorted List

0.31	0.43
0.32	0.48
0.36	
0.37	
0.38	
0.39	
0.41	
0.42	
0.42	
0.42	

Number of values= 12

Mean of values 0.39
Standard Deviation 0.05

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

31-33	**
34-36	*
37-39	***
40-42	****
43-45	*
46-48	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 830-835 m

Sorted List

0.36
0.36
0.38
0.43
0.46
0.47

Number of values= 6

Mean of values 0.41
Standard Deviation 0.05

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

36-38 ***
39-41
42-44 *
45-47 **

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 862 m

Sorted List

0.36	0.40	0.45
0.36	0.41	0.46
0.36	0.41	
0.37	0.41	
0.38	0.42	
0.38	0.42	
0.39	0.43	
0.39	0.43	
0.39	0.43	
0.39	0.43	

Number of values= 22

Mean of values 0.40
Standard Deviation 0.03

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

36-38	******
39-41	********
42-44	******
45-47	**

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 913 m

Sorted List

0.33	0.43
0.38	0.43
0.39	0.44
0.39	0.45
0.39	
0.39	
0.40	
0.40	
0.41	
0.42	

Number of values= 14

Mean of values 0.40
Standard Deviation 0.03

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

33-35	*
36-38	*
39-41	*******
42-44	****
45-47	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 982 m

Sorted List

0.41
0.42
0.46

Number of values= 3

Mean of values 0.43
Standard Deviation 0.02

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

41-43 **
44-46 *

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1105 m

Sorted List

0.39
0.43

Number of values= 2

Mean of values 0.41
Standard Deviation 0.02

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

39-41 *
42-44 *

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1190 m

Sorted List

0.39	0.48
0.39	0.49
0.40	0.53
0.42	0.54
0.42	
0.43	
0.45	
0.45	
0.47	
0.47	

Number of values= 14

Mean of values 0.45
Standard Deviation 0.05

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

39-41	***
42-44	***
45-47	****
48-50	**
51-53	*
54-56	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1406 m (Reworked)

Sorted List

0.59
0.61
0.65
0.67

Number of values= 4

Mean of values 0.63
Standard Deviation 0.03

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

59-61 **
62-64
65-67 **

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1509-15 m

Sorted List

0.39
0.40
0.40
0.53
0.60
0.64

Number of values= 6

Mean of values 0.49
Standard Deviation 0.10

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

39-41 ***
42-44
45-47
48-50
51-53 *
54-56
57-59
60-62 *
63-65 *

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1585 m

Sorted List

0.40	0.46	0.49
0.41	0.46	0.49
0.43	0.46	0.50
0.43	0.46	0.52
0.43	0.46	0.53
0.44	0.47	0.55
0.44	0.48	
0.45	0.48	
0.45	0.48	
0.45	0.48	

Number of values= 26

Mean of values 0.47
Standard Deviation 0.03

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

40-42	**
43-45	********
46-48	**********
49-51	***
52-54	**
55-57	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1709 m

Sorted List

0.46	0.56	0.60
0.47	0.57	0.61
0.47	0.57	0.62
0.49	0.57	0.63
0.49	0.58	0.65
0.49	0.58	
0.49	0.58	
0.49	0.59	
0.53	0.59	
0.55	0.60	

Number of values= 25

Mean of values 0.55
Standard Deviation 0.06

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

46-48	***
49-51	*****
52-54	*
55-57	*****
58-60	*******
61-63	***
64-66	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1790 m

Sorted List

0.53	0.64
0.55	0.66
0.55	
0.56	
0.56	
0.60	
0.61	
0.63	
0.63	
0.64	

Number of values= 12

Mean of values 0.60
Standard Deviation 0.04

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

53-55	*
56-58	****
59-61	**
62-64	****
65-67	*

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1805-1810 m

Sorted List

0.50	0.62
0.55	0.62
0.57	0.65
0.58	0.65
0.58	0.66
0.59	
0.59	
0.60	
0.60	
0.60	

Number of values= 15

Mean of values 0.60
Standard Deviation 0.04

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

50-52	*
53-55	
56-58	****
59-61	*****
62-64	**
65-67	***

VITRINITE REFLECTANCE VALUES

Well Name: Bus Swamp-1
Depth: 1815 m

Sorted List

0.54	0.58	0.63
0.55	0.58	0.63
0.56	0.59	0.64
0.56	0.59	0.64
0.56	0.60	0.64
0.56	0.61	0.64
0.56	0.61	0.65
0.56	0.62	0.66
0.57	0.62	0.66
0.58	0.62	

Number of values= 29

Mean of values 0.60
Standard Deviation 0.04

HISTOGRAM OF VALUES
Reflectance values multiplied by 100

54-56	**
57-59	**********
60-62	******
63-65	*******
66-68	**

GEOCHEMISTRY OF SEDIMENTS FROM BUS SWAMP-1

Data and analysis by:

R.E. Summons and I.A. Atkinson

Australian Geological Survey Organisation

Methods

Samples were hammered to chips which were subsequently crushed to 200-mesh in a ring crusher. Rock powders were stored in clean glass containers. Lids were lined with pre-baked aluminium foil. All items used to handle the samples were scrupulously washed with hot water and then distilled solvent between each use.

Total total organic carbon content was determined using a Leco IR-12 Carbon Determinator. Rock-Eval pyrolysis (Espitalié *et al.*, 1977) was carried out on 100 mg portions of powdered rock using a Girdel IFP-Fina Mark 2 instrument. Samples with less than 0.2 % TOC (i.e. 2mg/ g) are generally considered unsuitable for comprehensive hydrocarbon analysis because of the problems of contamination, although elemental and carbon isotopic analysis of their kerogens are considered to be reliable parameters at this low level of organic carbon. Samples with >0.2 % TOC were further assessed using Rock-Eval pyrolysis to establish the proportions of bitumen (S1 peak in kg/ Tonne) and kerogen (S2 peak in kg/ Tonne) and the relative maturity by Tmax (°C). If the S2 peak is above 0.5 (preferably >1) significant kerogen is present and a reliable indication of maturity can be established from the Tmax value. However, care must be exercised in the presence of a large S1 peak because this may lead to suppression of the pyrolysis temperature. Consistency of Tmax values within the range 420-470° over a large suite of samples from a particular unit is therefore considered to be a reliable indicator of the presence of immature to mature kerogens. Values of PI (S1/S1+S2) > 0.3 and Tmax in the range 440-470 are indicative of a sediment in the maturity phase for oil generation. Co-occurring bitumens in organic rich samples may be suitable for further hydrocarbon analysis to make more detailed palaeoenvironmental and maturity assessments.

Analysis of the Bus Swamp samples

The results of our analysis are shown in the accompanying table.

Core 2 samples from the well showed moderate TOC suggesting source rock potential. However, analysis of the Rock-Eval data show very high S3 (CO_2) generation and this is indicative of "dead" carbon or unstable carbonate minerals rather than kerogen (organic) carbon.

Samples toward the base of the hole (1756m, 1785m and SWC 4) show moderate levels of organic carbon accompanied by significant S2. Some minor source potential is suggested for the deepest sample (SWC 4) by the HI value of 150. The low HI values of the remainder of the samples suggest that the organic matter is probably gas-prone type III kerogen.

Where there is significant S2 (kerogen), the Tmax values are below all 440°. This indicates that the sediments intersected in this well have not yet reached the maturity zone for significant oil generation.

AGSO - ISOTOPE & ORGANIC GEOCHEMISTRY LABORATORY

AGSO No.	BASIN	INFORMATION	DEPTH	TMAX	S 1	S 2	S 3	P I	S2/S3	P C	TOC	H I	O I
6434		Batavia Downs	274-76m	440	0.03	0.6	0	0.05	0	0.05	0.63	95	0
6439	Otway	Bus Swamp SWC 41	657m	443	0	0.09	0	0	0	0	0.24	38	0
6435	Otway	Bus Swamp Core 1	830-35m	435	0.01	0.73	0	0.01	0	0.06	1.49	49	0
6440	Otway	Bus Swamp SWC 33	862m	436	0.01	0.49	0	0.02	0	0.04	0.8	61	0
6441	Otway	Bus Swamp SWC 30	913m	446	0	0.21	0	0	0	0.01	0.53	40	0
6436	Otway	Bus Swamp Core 2	1505-15m	439	0.06	0.54	15.15	0.1	0.03	0.05	2.7	20	561
6437	Otway	Bus Swamp Core 2 (base)	1509.8-15.8	439	0.06	0.56	17.33	0.1	0.03	0.05	2.5	22	693
6443	Otway	Bus Swamp 8 (swc?)	1756m	438	0.1	2.08	3.93	0.05	0.52	0.18	1.61	129	244
6438	Otway	Bus Swamp Core 3	1785-90m	438	0.06	1.32	0.82	0.04	1.6	0.11	1.29	102	64
6442	Otway	Bus Swamp SWC 4	1815m	431	0.39	5.23	1.66	0.07	3.15	0.46	3.5	149	47

Data : [illegible] Atkinson 03/10/93