1990/9
C.4

BMR PUBLICATIONS COMPACTUS
(LENDING SECTION)

Bureau of Mineral Resources, Geology & Geophysics

BUREAU OF MINERAL RESOURCES
LIBRARY
12 MAR 1990
CANBERRA, A.C.T.

RECORD

BMR RECORD 1990/09

ARAFURA SEA - SEISMIC RECONNAISSANCE WITH GEOCHEMISTRY
(PROJECT 121.24)

- RESEARCH CRUISE PROPOSAL -

by

A. MOORE, J.BRADSHAW, P.NAPIER and D.HEGGIE

1990/9
Copy 4

...ntained in this report has been obtained by the Bureau of Mineral Resources, Geology and Geophysics as part of the policy ...overnment to assist in the exploration and development of mineral resources. It may not be published in any form or used in ...tus or statement without the permission in writing of the Director.

BMR RECORD 1990/09

ARAFURA SEA - SEISMIC RECONNAISSANCE WITH GEOCHEMISTRY (PROJECT 121.24)

- RESEARCH CRUISE PROPOSAL -

by

A. MOORE, J.BRADSHAW, P.NAPIER and D.HEGGIE

R9000901

© Commonwealth of Australia, 1990
This work is copyright. Apart from any fair dealing for the purposes of study, research, criticism or review, as permitted under the Copyright Act, no part may be reproduced by any process without written permission. Inquiries should be directed to the Principal Information Officer, Bureau of Mineral Resources, Geology and Geophysics, GPO Box 378, Canberra, ACT 2601.

CONTENTS

ILLUSTRATIONS

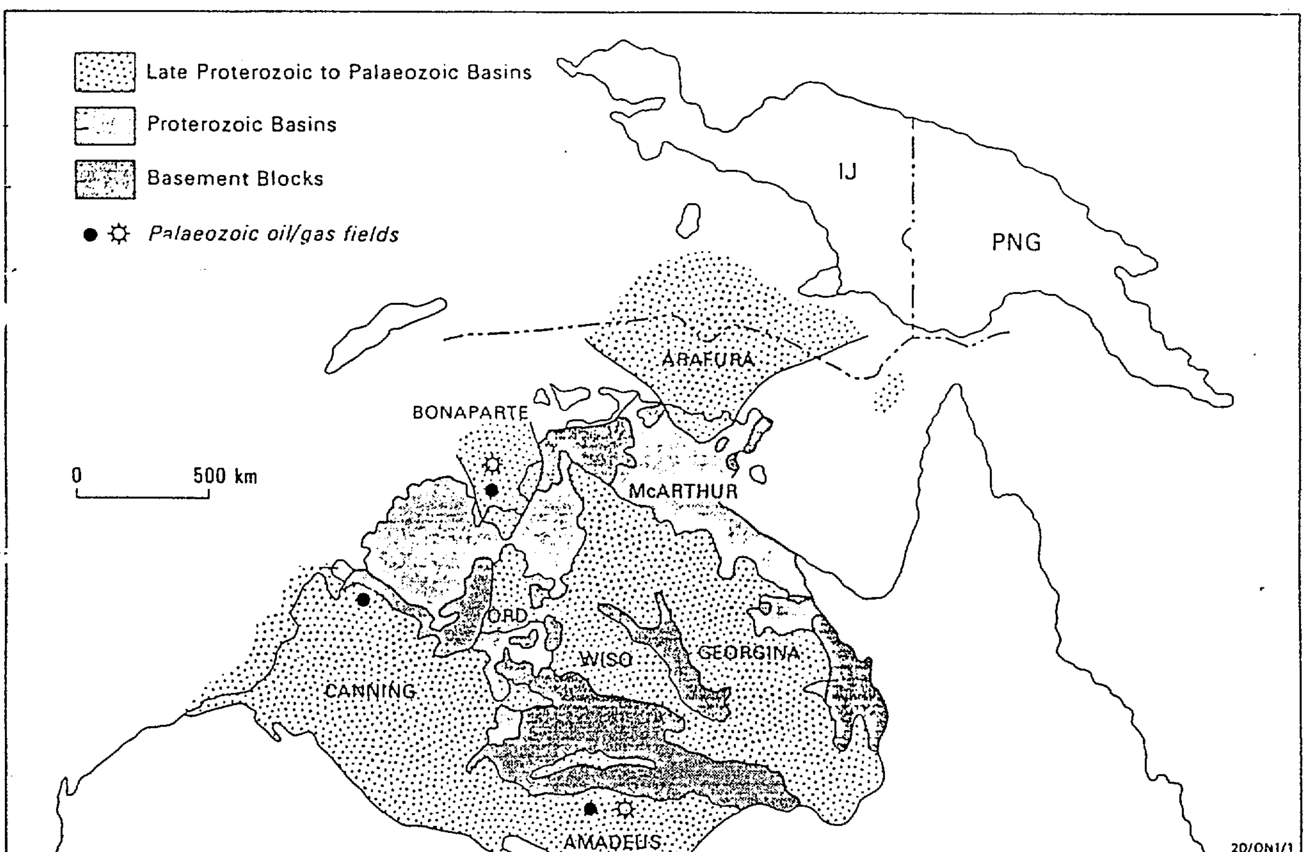


Figure 1 Northern Australia and New Guinea, showing Palaeozoic and Proterozoic basins.

(after Bradshaw et al, 1990)

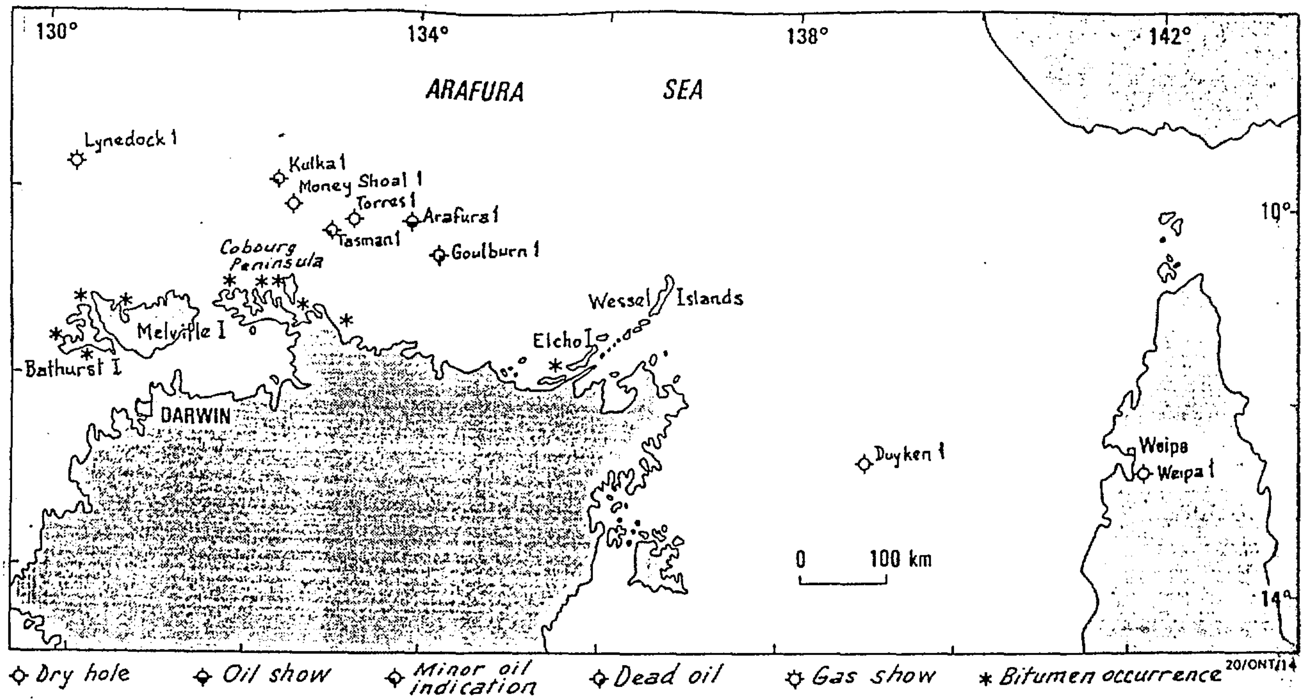


Figure 2 The Arafura Sea, showing oil exploration wells and hydrocarbon shows.

(after Bradshaw et al, 1990)

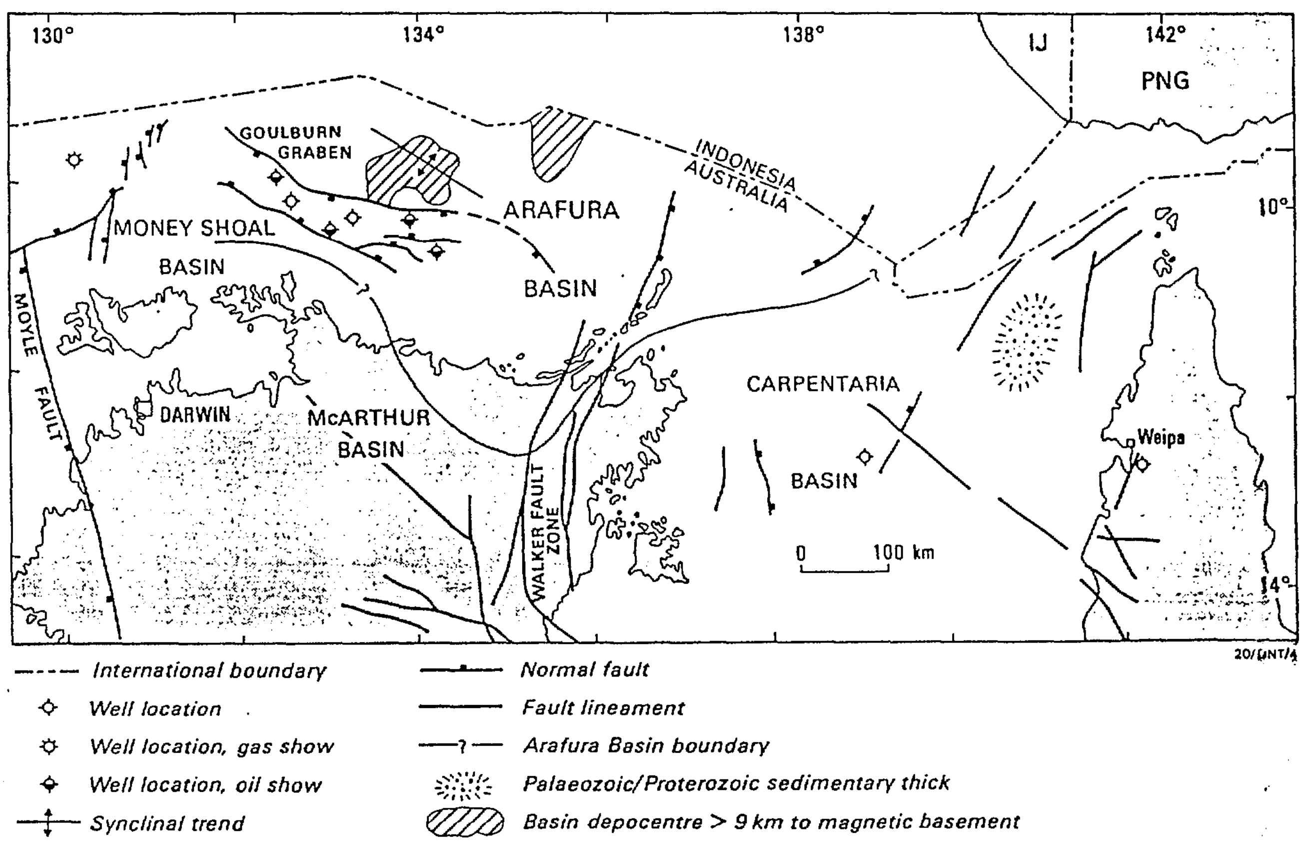


Figure 3 The Arafura Basin, showing major faults.

(after Bradshaw et al, 1990)

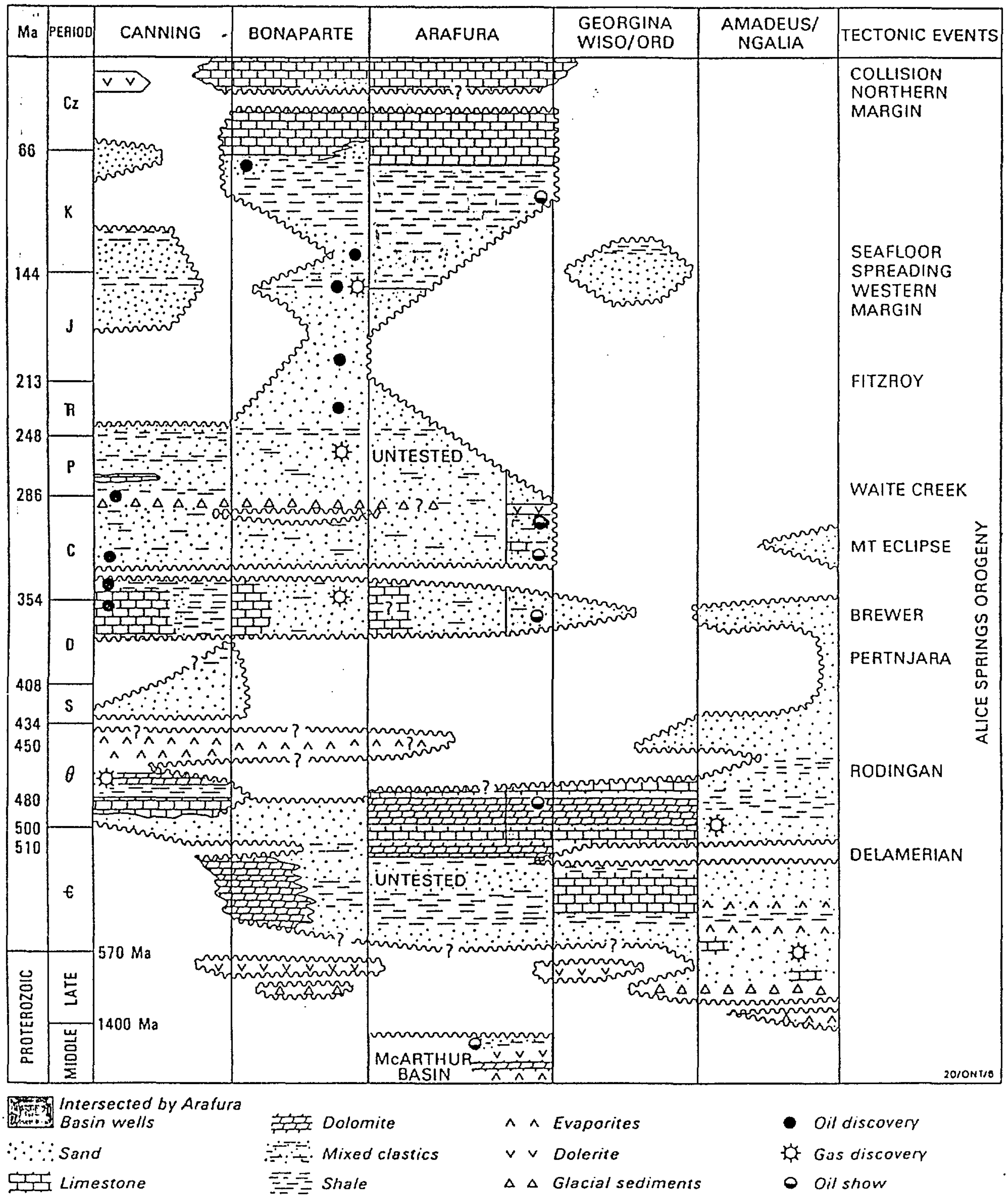
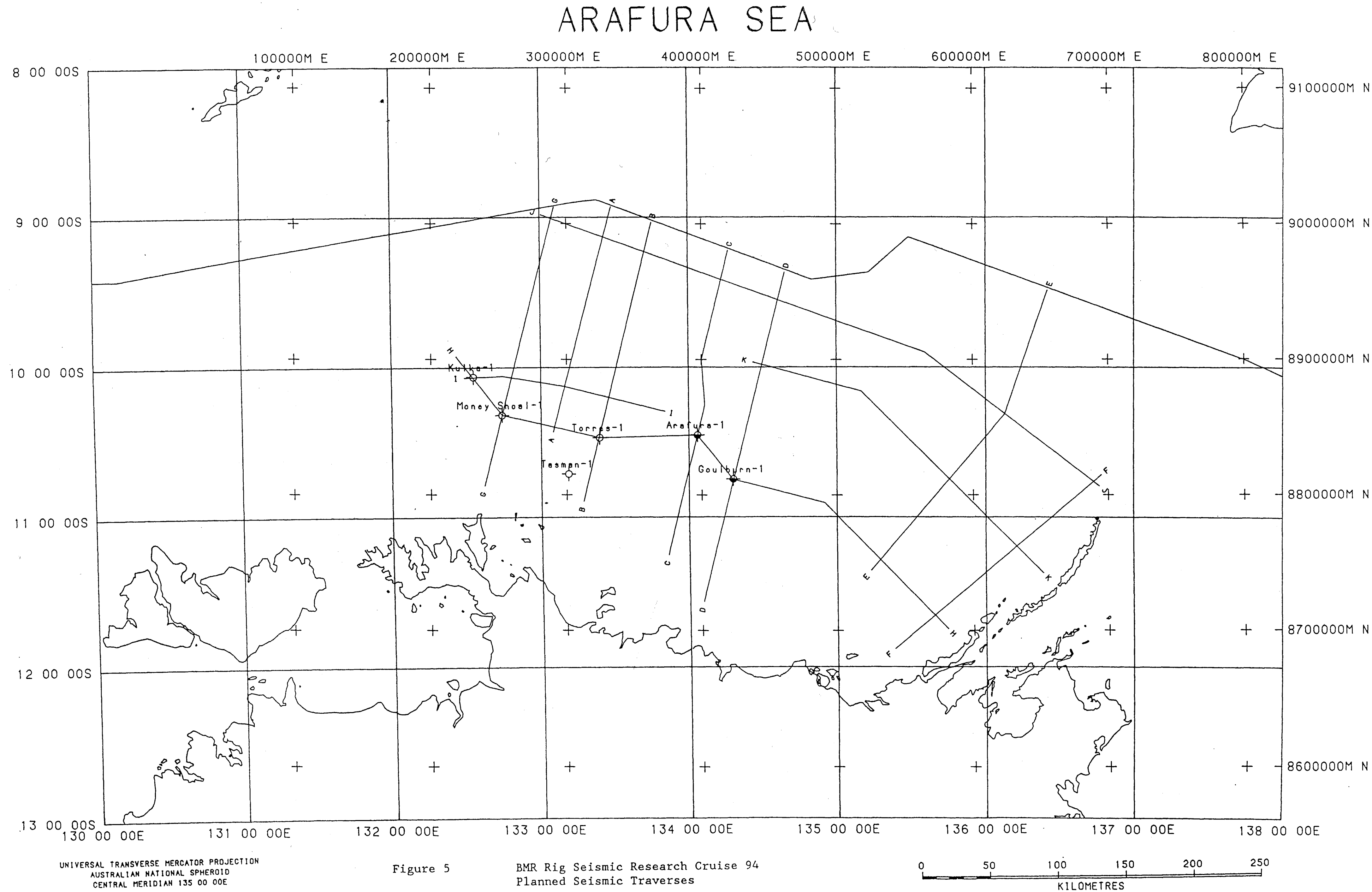


Figure 4 Northern Australian Basins, comparative stratigraphy.

(after Bradshaw et al, 1990)



UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 135 00 00E

Figure 5 BMR Rig Seismic Research Cruise 94
Planned Seismic Traverses

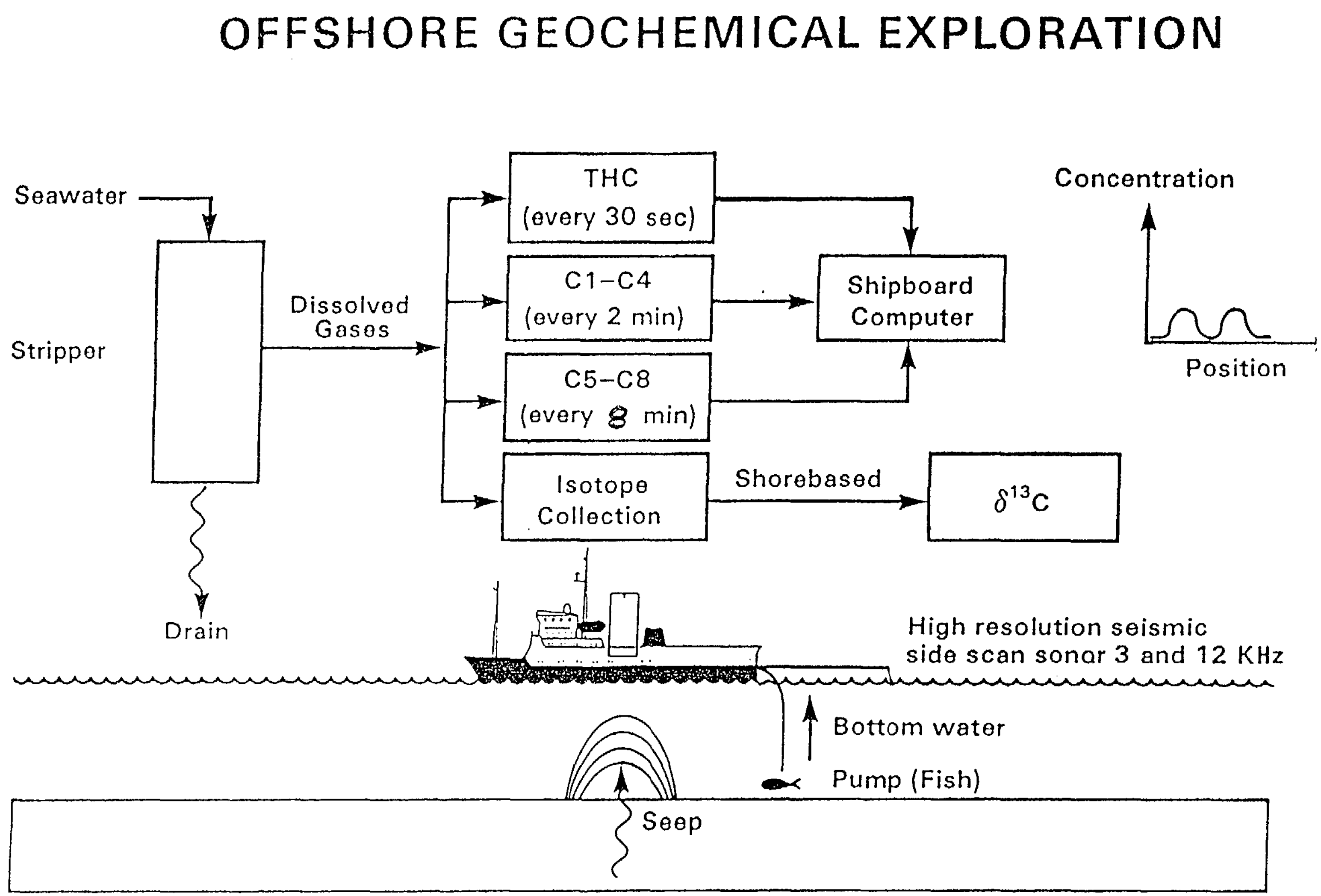


Figure 6 Direct Hydrocarbon Detection (DHD) Schematic

SUMMARY

Large areas of the Arafura Sea in Australian waters are virtually unknown geologically, with seismic coverage being limited to widely separated traverses, some of which have poor sub-seabed penetration.
It is proposed that the Rig Seismic be used for one month in early 1990 to carry out reconnaissance of the eastern Arafura Basin. A maximum of nearly 3000 kilometres of seismic multifold coverage will be acquired, together with magnetic and gravity data and geochemical analysis of near-bottom sea-water for hydrocarbons. Seismic refraction profiles at selected sites will be recorded. The aims will be to complete the framework of essential seismic reconnaissance in the sparsely-explored and little-known eastern part of the Arafura Basin, to investigate the architecture of the graben in the western and central parts of the Basin, and to test the water for traces of thermogenic hydrocarbons, one of the indicators of the generation of hydrocarbons in sub-seafloor sediments.

INTRODUCTION

The Arafura Basin (Figure 1) is the most extensive of the basins underlying the shallow Arafura Sea, and contains sediments of Cambrian to Permo-Triassic age. The west-northwest-trending Goulburn Graben (new name, see Bradshaw, Nicholl and Bradshaw, 1990) within it contains up to 10 kilometres of Palaeozoic sediments. A short exploration phase from 1981 to 1986 led to partial delineation of the basin sediments and structure, which has been recently reviewed (Petroconsultants, 1989).
The six exploration wells in the basin (Figure 2) have all been sited on structural targets along the Goulburn Graben (Figure 3), and most of the modern seismic coverage is within it. The majority of the Cambrian and Permo-Triassic sequences remain untested and extensive areas of the basin outside the graben are virtually unexplored.
In a current study (Bradshaw, Nicholl and Bradshaw, 1990, in prep.), extensive redating of the Cambrian to Devonian sequences and analysis of the regional geology has highlighted several new concepts. These have implications for the understanding of basin architecture and the tectonic history of Northern Australia, and for petroleum exploration in the area and beyond. Important features that have been recognised include, late tectonics in the Goulburn Graben and variations in style along its length, Lower Palaeozoic stratigraphic intervals that are of equivalent age to the oil source rocks in the Amadeus and Canning basins, the continuance of the upper and lower Palaeozoic north of the graben to the Australian - Indonesian border, the existence of the lower Palaeozoic sequence to the northeast of the Wessel Islands, and the prevalence of relatively low geothermal gradients, thus raising the petroleum potential of the older sequences.
The proposed cruise will pursue these insights with seismic traverses both across and along the Goulburn Graben to acquire

data on its deeper structure; with tie lines from the graben northward toward the Australian-Indonesian border; with infill seismic in the eastern part of the basin; with a seismic tie near to Lower Palaeozoic outcrop; and with the acquisition of magnetic and gravity, dissolved hydrocarbon gas and refraction data.

GEOLOGICAL SETTING

The Arafura Basin is a broad platform sequence situated on the northern margin of Australia mostly beneath the shallow waters of the Arafura Sea. Structurally it consists of a northern and a southern platform separated by a major graben. The Cambrian to Permo-Triassic Arafura Basin sequence is unconformably overlain by the mid-Jurassic to Recent Money Shoal Basin sequence and is underlain by Proterozoic sediments of the McArthur Basin (Figure 4). In the Goulburn Graben (formerly called Arafura Graben or Money Shoal Graben or Pre-Mesozoic Graben) there is a Palaeozoic sequence over 10 km in thickness, whilst on the northern and southern platform there are respectively at least 5 and 3 km of those sediments preserved.

BRIEF EXPLORATION HISTORY

The existence of a large Palaeozoic basin to the north of Australia was suspected for many years from the outcropping Cambrian sequence on Elcho Island (Wade, 1924; Plumb, 1965; Plumb et al., 1976) and aeromagnetic surveys (Balke & Burt, 1976). Oil exploration began in the early 1920s with the drilling of several shallow holes (<100 m) on Elcho Island in response to bitumen occurrences (Plumb, 1965). Offshore, Shell drilled Money Shoal 1 in 1971, which primarily tested a Mesozoic sequence. Tests of the Palaeozoic sequence of the Arafura Basin occurred between 1983 and 1986 with the drilling of Tasman 1, Torres 1, Arafura 1, Kulka 1 and Goulburn 1. All of these wells were sited offshore in the southern part of the basin along the Goulburn Graben. There were oil shows in most wells, and four source rock intervals were intersected. Arafura 1 was the most encouraging, encountering oil shows over a gross interval of 425 m in the Devonian and Ordovician and recording total organic carbon (TOC) values of up to 8.65% in the Middle Cambrian.

Recent seismic surveys of regional significance and with good subsurface penetration include

Wessel Marine Seismic Survey 1972, shot by Western Geophysical for Beaver Exploration, Line ID - WM and W.

M81A Seismic Survey 1981, by GSI for Esso, Line ID - M81.

Arafura Sea S81 Survey 1981, by GSI for Sion Resources, Line ID - S81.

AM81 Survey 1981, by GSI for Mincorp, Line ID AM81.
DS81 Survey 1981, by Western Geophysical for Diamond Shamrock, Line ID DS-81.
DS84 Survey 1984, by Western Geophysical for Diamond Shamrock, Line ID DS-84.
The most recent seismic surveys in the area are -
HA88A Seismic Survey by Halliburton for BHP, Line ID HA88A, PSLA ID 88/43
HA88B Seismic Survey by Halliburton for BHP, Line ID HA88B, PSLA ID 89/1
HA89A and HA89B, 1989, by Halliburton for BHP, Line ID HA89A and HA89B,

CRUISE OBJECTIVES

The objectives of the cruise are as follows:-

*to investigate the nature of the Goulburn Graben by acquiring deep information about the dip and relationship of the controlling faults

*to tie the seismic succession in or around the graben to the outcrop of Cambrian-age rocks on Elcho Island

*to investigate the eastward extent of the graben

*to fill gaps in the seismic coverage of the eastern part of the Arafura Basin and to tie it to seismic traverses east of the Wessel Rise.

*to investigate seismic refraction velocities of sediments, as an aid to prediction of the age of seismic sequences.

*to test the practicability of acquiring near-bottom water samples for geochemical analysis simultaneously with seismic,by continuous sampling about 10 metres from the bottom.

*to contribute new data on hydrocarbon occurrence by seeking anomalous concentrations of light hydrocarbons using Direct Hydrocarbon Detection (DHD).

CRUISE PLAN

The cruise is scheduled for a 29-day period in early 1990, from the latter half of February through mid-March, commencing and finishing in Darwin.

Eleven lines of multifold seismic traverse will be shot, a total of 2852 kilometres. The traverses are shown on Figure 5 as lines A to K. DHD will be done on as many of the lines as possible, with those through the existing wells and in or adjacent to the Goulburn Graben given priority (in general, the most westerly lines). A schematic diagram of the DHD method constitutes Figure 6. The co-ordinates of the waypoints of the lines are listed in Appendix 1. The geophysical equipment that will be used is shown in Appendix 2. The parameters of data collection are detailed in Appendix 3.

The co-ordinates of oil exploration wells near which the seismic traverses will pass are included in Appendix 1.

Magnetic and gravity data will be collected simultaneously with the seismic.

Up to five sonobuoys will be deployed.

DIRECT HYDROCARBON DETECTION (DHD)

Direct Hydrocarbon Detection is designed to contribute data on hydrocarbons generated from source rocks, by searching for hydrocarbon vents and seeps from the underlying sediments to seawater. Hydrocarbon vents and seeps produce anomalous concentrations of light hydrocarbons in seawater with molecular compositions that are distinctively different from 'background' of biogenically produced hydrocarbons. Furthermore, the molecular compositions of thermogenic hydrocarbon vents and seeps may be used to infer the 'source' of that seep, i.e., liquids, condensate or dry gas.

The method used on the RV 'Rig Seismic' can be summarised as follows (refer to Figure 6).

Seawater is continuously delivered, via a submersible towed pump (the 'fish') into the geochemical laboratory aboard the ship. A ship speed of up to six knots is possible in depths characteristic of the continental shelves, but when geochemistry is used simultaneously with seismic reflection profiling aboard Rig Seismic the speed is limited by seismic requirements to four to five knots.

The water is continuously degassed in a vacuum chamber and the resulting headspace gas is injected into three gas chromatographs which sequentially sample the flowing gas stream and measure a variety of light hydrocarbons. Total hydrocarbons are measured every thirty seconds. Light hydrocarbons, methane through butane are measured every two minutes and intermediate hydrocarbons, C5 through C8 are measured every 8 minutes.

Fish altitude from bottom, depth of the fish in the water, hydrographic data (temperature and salinity) and continuous navigation are recorded on the hydrocarbon data acquisition computer. All data are recorded and displayed continuously so that anomalies in the water column can be quickly and easily recognised and additional measurements can be made when appropriate.

Samples for isotopic measurements may be taken on the ship when seeps are detected. These samples are stored for subsequent analyses in the shore laboratory.

The sensitivity of the method is high, allowing detection of 10 parts per billion in the stripped headspace sample, corresponding to 200 nanolitres of THC per litre of seawater.

At 4 knots, the measurement of THC is made at distances over the seafloor of about 70 m; for methane to butane at distances of about 350 m and pentane to octane at about 1400 m.

REFERENCES

BALKE, B., BURT, D., 1976 - Arafura Sea Area. In LESLIE, R.B., EVANS, H.J., KNIGHT, C.I., (Eds.), Economic Geology of Australia and Papua New Guinea, 3. Petroleum. Australian Institute of Mining and Metallurgy, Monograph Series 7, 209 - 212.

BRADSHAW, J., NICOLL, R.S., BRADSHAW, M.T., 1990 (in press)-The Cambrian to Permo-Triassic Arafura Basin, Northern Australia. APEA JOURNAL, 30.

PETROCONSULTANTS AUSTRALIA Pty Ltd, 1989 - Arafura Basin. Northern Territory Geological Survey Petroleum Basin Study.

PLUMB, K.A., 1965 - Wessel Islands/Truant Island, N.T. 1:250,000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SC/53-15.

PLUMB, K.A., SHERGOLD, J.H., STEFANSKI, M.Z., 1976 - Significance of Middle Cambrian trilobites from Elcho Island, Northern Territory. Bureau of Mineral Resources, Australia, Journal of Australian Geology and Geophysics 1(1), 51 -55.

WADE, A., 1924 - Petroleum prospects, Kimberley District of Western Australia and Northern Territory. Parliament of the Commonwealth of Australia Report 142.

APPENDIX 1

CO-ORDINATES OF SEISMIC LINES - WAY POINTS
LINE LENGTH in KM
DECIMAL LATITUDES (SOUTHERN HEMISPHERE IS NEGATIVE)
AND LONGITUDES (EASTERN HEMISPHERE IS POSITIVE)

A	173km	1	-10.428619	133.080495	
		2	-8.931949	133.482201	
B	213km	1	-10.893975	133.283549	
		WELL	-10.4684	133.3938	TORRES-1
		3	-9.034857	133.753238	
C	115km	1	-11.254344	133.855568	
		WELL	-10.4521	134.0562	ARAFURA-1
	117km	3	-10.253433	134.108585	
		4	-9.950016	134.088749	
		5	-9.224763	134.269837	
D	253km	1	-11.565488	134.090707	
		WELL	-10.7480	134.2957	GOULBURN-1
		3	-9.369315	134.651926	
E	250km	1	-11.358208	135.226782	
		2	-10.310443	136.129764	
		3	-9.486424	136.417073	
F	200km	1	-11.879888	135.385607	
		2	-10.717272	136.782584	
G	213km	1	-10.787535	132.614155	
		WELL	-10.3161	132.7369	MONEY SHOAL-1
		3	-8.931590	133.098571	
H	54km	1	-9.926194	132.430907	
		WELL	-10.0630	132.5447	KULKA-1
	75km	3	-10.3161	132.7369	MONEY SHOAL-1
	73km	4	-10.4684	133.3938	TORRES-1
	42km	5	-10.4521	134.0562	ARAFURA-1
	70km	6	-10.7480	134.2957	GOULBURN-1
	140km	7	-10.906902	134.915269	
		8	-11.747250	135.740262	
I	152km	1	-10.068013	132.488624	
		WELL	-10.0630	132.5447	KULKA-1
		2	-10.057266	132.744404	
		3	-10.126335	133.161395	
		4	-10.294898	133.837456	
J	300km	1	-8.983517	133.009393	
	162km	2	-9.901186	135.591372	
		3	-10.792390	136.765140	
K	250km	1	-9.967161	134.437270	
		2	-10.160702	135.165354	
		3	-11.375220	136.386428	

APPENDIX 2: List of Geophysical Equipment

Seismic System

Streamer: 3600m Teledyne hydrophone analogue streamer configured as 96 x 37.5m groups.
- 30 hydrophones per 37.5m group
- 5V/bar sensitivity
- ~15 microvolts noise; maximum ambient at 5 knots
- 6 Syntron RCL-3 individually adressed cable levellers

Source Array:
- 52.4/73.4 litre (3200/4480 cubic inch), 28-element tuned Texas Instruments air-gun array; 20 elements (3200 cubic inch) equally divided into two strings in use at any one time.
- Teledyne gun signature phones, gun depth sensors, and I/O SS-8 shot sensors
- 4 x Price A-300 compressors, each rated at 300scfm @ 2000 psi

Recording
- BMR designed and built seismic acquisition system based on Hewlett-Packard minicomputers
- 96 channel digitally controlled preamp/filters
- bit accuracy
  - 12 bit floating point with 4 bit dynamic accuracy
  - 15 bit integer card
- 6250 bpi Telex tape drives
- data read after write in demultiplexed SEG-Y format
- 2 or 4 msec sampling with 96 channels
- streamer noise, leakage, and individual group QC
- source array timing QC
- recording oscillator and 4 seismic monitor QC

Bathymetric System

- Raytheon deep-sea echo-sounder; 2 kW output at 12 kHz
- " sub-bottom profiler; 2 kW " 3.5kHz

Gravity Meter

- Bodenseewerk Geosystem KSS - 31 marine gravity meter

Navigation Systems

GPS System - Magnavox T-Set GPS navigator

Prime Transit System
- Magnavox MX1107RS dual channel satellite receiver
- Magnavox MX610D dual-axis sonar doppler speed log
- Sperry gyro-compass

Secondary Transit System
- Magnavox MX1142 single channel satellite receiver
- Raytheon DSN450 dual-axis sonar doppler speed log
- Robertson gyrocompass

Data Acquisition System

- data acquisition system built around Hewlett-Packard 2117 F-Series minicomputer, with tape drives, disc drives, 12" and 36" plotters, line printers and interactive terminals

APPENDIX 3

ACQUISITION PARAMETERS

Source	2x1600 cubic inch air-gun arrays
Shot Spacing	37.5m
Shooting Interval	18.2 seconds at 4 knots
Cable Length	3600m active; 4200m to tail buoy
Group Interval	37.5m
No. of Channels	96
Near Offset	approx. 200m
Far Offset	approx. 3800m
Cable Depth	10 - 12m
Recording Fold	48
Record Length	12 seconds
Sample Rate	2 or 4 milliseconds
Filter Settings	8 Hz Low cut; 64 or 128 Hz High cut
Amplifier Gain	Pre-amplifiers 128 Hz. IFP to be used on all lines
Field Tape Density	6250 bpi
Tape Format	SEG Y

APPENDIX 4: Science Personnel

P.Napier	Co-chief scientist
A.Moore	Co-chief scientist
G. Heal	Systems supervisor
E.Chudyk	Systems specialist
K. Revill	Science technician
J. Kossatz	Science technician
T.McNamara	Science technician
D. Pryce	Science technician
H. Reynolds	Science technician
A. Warnes	Science technician
D. Holdway	Electronics technician
G. Burren	Electronics technician
H. Hudson	Electronics technician
G. Bickford	Geology supervisor
C. Tindall	Geology technician
G. Sparksman	Geology technician
P. Attenborough	Geology technician
B. Dickinson	Mechanical technician
C. Green	Mechanical technician
D. Sewter	Mechanical technician
C. Dyke	Mechanical technician