Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

RECORD 1991/8

RESEARCH CRUISE PROPOSAL

AREA "A" OF THE ZONE OF COOPERATION: DEEP CRUSTAL ARCHITECTURE AND HYDROCARBON MIGRATION

PROJECT 121.22

PROGRAM MANAGER:-G.W. O'BRIEN

SCHEDULE:- APRIL-MAY 1991

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EXECUTIVE SUMMARY

The Division of Marine Geosciences and Petroleum Geology (Bureau of Mineral Resources (BMR)) seeks the approval of the Joint Development Authority to carry out a research program within Area "A" of the Zone of Cooperation, Timor Sea, during April-May 1991. This program will be conducted using its research vessel, the R.V. *Rig Seismic* (see Appendix 1) and will consist of a minimum of 2990 kilometres (maximum 4140 kms) of regional deep crustal (14 second record length) seismic reflection data (see Figure 1 & Enclosure 1; Appendix 2). Data quality in the shallow (top 6 seconds TWT) section will also be high, and thus the survey will also provide regional seismic tie-lines across the Zone of Cooperation. A water column hydrocarbon geochemical program (Direct Hydrocarbon Detection (DHD)) will be carried out simultaneously with the seismic acquisition for the entire survey (see Appendix 2). Subject to Joint Authority approval, the dates for carrying out this 35 day program would be between April 5 and May 9, 1991.

The principal objectives of this research program are:

i.)To understand the deep crustal architecture of the Zone of Cooperation and its relationship to the associated tectonic elements in the area;
ii.)To understand the control of this underlying architecture on structural reactivation processes and petroleum trap formation within the Zone of Cooperation and its associated tectonic elements;
iii.)To provide regional seismic tie-lines across the Zone of Cooperation;
iv.)To understand the mechanisms of hydrocarbon generation, migration and entrapment within the Zone of Cooperation and its associated tectonic elements.

The BMR has considerable in-house geological and geophysical expertise concerning the Timor Sea region and presently has an active research program within the area. Moreover, BMR has experience conducting the proposed type of survey, both within the Timor Sea and elsewhere

around the Australian continental margin. Consequently, the results of this survey would be rapidly and fully integrated with previously completed BMR Timor Sea programs, which would lead to a much better understanding of the area's geology and petroleum prospectivity. Data from the proposed program would be integrated with:

a.)Deep crustal, high resolution seismic and water column geochemical (DHD) data which were collected within the Vulcan Graben during October-December 1990.

b.)High resolution seismic and DHD data which were collected within the Sahul Syncline, the Malita Graben and Petrel Sub-Basin during February-March 1991.

c.)Deep crustal data from the Petrel Sub-Basin which will be collected during an upcoming BMR research survey.

While the proposed deep crustal seismic reflection data will be designed to determine the principal structural elements and image the crust and upper mantle, it will also provide regional stratigraphic ties, both between exploration wells and between the adjacent tectonic elements in the area.

In the light of our experience in the Vulcan Graben, we believe that the water column geochemical program can potentially provide important information on both the type and distribution of reservoired hydrocarbons within the ZOC.

The water column geochemical data will be processed progressively during acquisition and will be fully processed by the completion of the survey. A full interpretive report will be available within 4 weeks of the end of the survey. Processing of the seismic data will proceed as expeditiously as possible, subject to the availability of a suitable processing contractor.

1. BACKGROUND

The Australian Bureau of Mineral Resources has an ongoing Continental Margins Program which is investigating the structural development and petroleum prospectivity of Australia's continental shelf and slope. A considerable part of this program has been focussed on obtaining deep crustal seismic data around the margin so that the deep crustal architecture of the shelf and slope can be determined. These studies allow the actual mechanisms of basin formation to be established and also provide the key to understanding how the deep structures have been reactivated. Structural reactivation is proving to be a vital facet of hydrocarbon entrapment on the Australian margin.

In the past year, the focus of BMR's program has switched to the northern Australian margin. Deep crustal programs have been conducted in the Arafura Basin to the east of the Zone of Cooperation and immediately to the southwest in the Vulcan Graben (see Figure 1). Within the next twelve months, further deep crustal surveys are programmed for the Petrel Sub-Basin (southeast of the ZOC), the Browse Basin and the southern Northwest Shelf, including the offshore Canning Basin. All of these programs will link directly into the previously collected data sets. Following acquisition of this data, the BMR will have a unique and consistent data set which will allow the deep crustal architecture of the entire northern Australian margin to be characterised.

In addition to the deep crustal program, the BMR has been acquiring underway water column geochemical data around the Australian margin. This remote sensing tool continuously measures the hydrocarbon content and composition in seawater which is pumped to the ship from near the sea bottom (see Appendix 2). This tool has proven effective in delineating the most prospective parts of sedimentary basins and can potentially discriminate between oil and gas-prone areas. Very interesting results have been obtained in the Vulcan Graben, the Sahul Syncline, the Malita Graben and the Petrel Sub-Basin in the last few months.

As part of our ongoing research program in northern Australia, BMR wishes to apply to the Joint Authority for permission to conduct a 35 day

survey within the Zone of Cooperation in April-May 1991 (see Figure 1; Enclosure 1). During this survey, we will carry out simultaneous deep crustal seismic and underway geochemical acquisition. As this proposed program will form one part of a much larger study that BMR is undertaking in the region, the data collected within the ZOC will be fully and rapidly integrated with our existing, or soon to be collected, data sets in the region. This integration will provide a unique understanding of the hydrocarbon prospectivity of the Zone of Cooperation which will be of considerable benefit to the petroleum exploration industry.

2. PROJECT OBJECTIVES AND RATIONALE

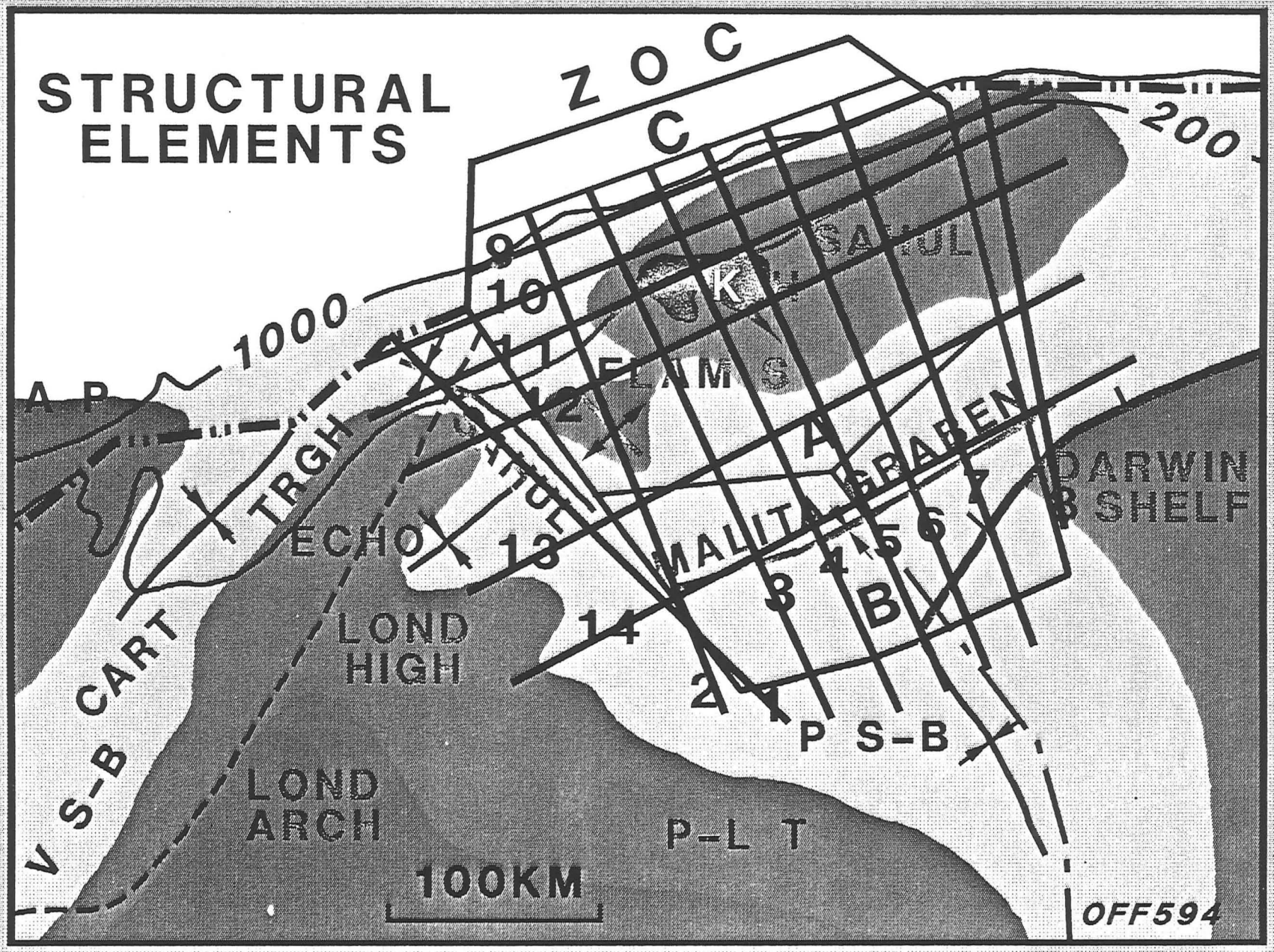
TECHNICAL AND SCIENTIFIC OBJECTIVES

i.)Deep Crustal Seismic Reflection Data: To acquire, in and around the ZOC, approximately 3000 line km of deep crustal seismic reflection data.

The deep crustal study has the objective of defining the three dimensional basinal architecture of the Zone of Cooperation and linking the architecture of the ZOC into the adjacent structural elements. The survey will be sufficiently detailed to allow the definition of the major structural features in the region. This definition will, in turn, provide an understanding of how these major structures have controlled basin development, sedimentation history, petroleum trap formation (including via reactivation), source rock accumulation, and the migration of hydrocarbons within the ZOC. The data will also provide regional stratigraphic ties, both between exploration wells and between the adjacent tectonic elements in the area.

The program will consist of a maximum of 14 lines: 8 dip lines and 6 strike lines. The details of the lines are given in Table 1. The lines have been subdivided into three priority categories: low, medium and high. Where logistics allow it, high priority lines will be completed first, medium next and low priority lines will be completed at the end of the survey. Total line kilometres for all of the proposed lines is 4140 kms; for high and medium priority lines 3560 kms and for only high priority lines 2990 kms. Assuming a total acquisition time of approximately 30 days (allowing 5 days for transiting and cable testing), then the average

Figure 1. Proposed deep crustal seismic and water column geochemical program within the Zone Of Cooperation, Timor Sea, northwestern Australia


STRUCTURAL ELEMENTS
ZOCC
200
1000
SAHUL
KELAMS
AP
TRGH
ECHO
MALITA GRABEN
DARWIN SHELF
VS-B CART
LOND HIGH
LOND ARCH
PS-B
P-L T
100KM
OFF594

production rates required to achieve the above line kilometres would be 138 km/day (4140 kms), 119 km/day (3560 kms) and 100 km/day (2990 km/day). Seismic refraction and wide angle reflection data will be collected using sonobuoys utilising shots fired during the seismic reflection survey, to provide velocity control to facilitate interpretation of the reflection data.

Table 1. Line lengths and orientation for the proposed BMR survey in the Zone of Cooperation, Timor Sea.

Line Number	Line Length (kms)	Orientation	Priority
1	250	Dip	Low
2	250	Dip	High
3	290	Dip	High
4	290	Dip	High
5	290	Dip	High
6	290	Dip	High
7	290	Dip	High
8	220	Dip	High
9	220	Strike	Medium
10	350	Strike	High
11	350	Strike	High
12	370	Strike	High
13	330	Strike	Low
14	350	Strike	Medium

Total Line Kilometres All Lines: 4140 kms
Total Line Kilometres High and Medium Priority Lines: 3560 kms
Total Line Kilometres: High Priority Lines: 2990 kms

Geological structures within the ZOC reflect multiple periods of rifting and extension which relate to the formation of the initial Paleozoic rift, later Mesozoic rifting, and finally, continental margin formation. In addition, geologically recent structural reactivation, due to the interaction between the major Tertiary compressional pulse (associated with collision along the northern margin of Australia and Timor) and the underlying architecture of the ZOC, was probably instrumental in

providing Mesozoic structural traps and, importantly, expulsion and migration pathways for hydrocarbons. Our proposed deep crustal data set potentially provides an understanding of which (and how) the deep-seated Palaeozoic and Mesozoic structural features were reactivated during the Tertiary, and consequently, which trends are most likely to be productive.

ii.)Remote Sensing Geochemical Data: To acquire, in and around the ZOC, approximately 3000 line km of direct hydrocarbon detection water column data

The Direct Hydrocarbon Detection data (DHD) data will be collected simultaneously with the deep crustal seismic data, thereby allowing geochemical anomalies to be related to sub-seafloor geology. The DHD data will help to establish the nature (and migration pathways) of the hydrocarbon charge emanating from the Sahul Syncline and Malita Graben at the present day (see Appendix 2). This objective may be particularly important because of the possibility of flushing oil from ZOC reservoirs along the margins of the Sahul Syncline (and Malita Graben) with gas generated from source rocks which are now overmature. The DHD program will also potentially provide information on the probable type (i.e. gas versus oil) and distribution of hydrocarbon accumulations within the ZOC 'proper'.

3. PROGRAM CONTINGENCIES

If there are difficulties in fulfilling the stated acquisition program due to bad weather or equipment failure, then contingency programs will be undertaken to ensure the best use of the available survey time within the ZOC. These contingencies are:

i.)**Due to bad weather:**Deep crustal acquisition will cease and direct hydrocarbon detection work will continue until the weather conditions improve to the point where seismic acquisition can recommence.

ii.)**Due to deep crustal seismic equipment failure:**In the event that deep crustal seismic acquisition becomes impossible because of the loss of the deep crustal seismic cable or failure of the sleeve gun array etc, a high resolution seismic cable will be deployed with a 400 cubic inch capacity water gun array (see Appendix 2). High resolution seismic

acquisition will then commence simultaneously with direct hydrocarbon detection and also side-scan sonar acquisition. If a satisfactory high resolution seismic and DHD program is completed, then a sediment coring program will be undertaken over a variety of geological structures within the ZOC. This coring program will be integrated with the DHD and high resolution seismic program. The molecular and isotopic compositions of the light hydrocarbon gases within the pore waters within the sediments will be measured onboard the *Rig Seismic*. The integration of both sediment and water column (DHD) hydrocarbon data will allow an assessment of the relative usefulness of these techniques as remote sensing tools in this area.

4. EXPECTED PRODUCTS FROM PROJECT 121.22

The following products can be expected to result from this project:-

- Regional deep crustal seismic sections showing the main structural elements of the Zone of Cooperation and their relationship to the surrounding structural elements.

- Revised regional tectonic elements maps and structural sections.

- Regional seismic stratigraphic ties, both between exploration wells and between the adjacent tectonic elements in the area.

- Regional maps of the distribution of light hydrocarbons in the water column the relationship of any detected geochemical anomalies to sub-seafloor geology.

- Basin-wide burial and thermal geohistory analyses of relevant exploration wells (and synthetically-generated locations) to constrain the timing of hydrocarbon generation and likely migration pathways.

Any Contingency Program would include:

• High resolution seismic data with particular emphasis on the resolution of structural features in the upper 2.0 seconds TWT. Maps over selected structural features.

• Side-scan sonar derived maps of the orientation and distribution of faults that have a surface expression.

• Hydrocarbon gas geochemistry of sediments across the Zone of Cooperation. The coring and side-scan sonar programs will also provide useful information on the Quaternary sediments across the ZOC, which will be useful from an engineering (i.e. rig site survey) perspective.

5. ACKNOWLEDGEMENTS

I wish to thank Dr Paul Williamson and Mr Phil Symonds for helpful suggestions concerning the proposed program.

APPENDIX 1

GENERAL DETAILS:-RESEARCH VESSEL RIG SEISMIC

R/V Rig Seismic is a seismic research vessel with dynamic positioning capability, chartered and equipped by BMR to carry out the Continental Margins Program. Thc ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It is registered in Newcastle, New South Wales, and is operated for BMR by the Federal Department Of Transport and Communications.

Gross Registered Tonnage:	1545 tonnes	
Length, overall:	72.5 m	
Breadth:	13.8 m	
Draft:	6.0 m	
Engines:	Main: Norma KVMB-12	2640 HP/825 rpm
	Aux: 3x Caterpillar	564 HP/482 KVA
	1x Mercedes	78 HP/56 KVA
	Shaft generator:	AVK 1000KVA; 440 V/60 Hz
Side Thrusters:		2 forward, 1 aft, each 600 HP
Helicopter Deck:		20 m diameter
Accommodation:		39 single cabins and hospital

APPENDIX 2

SCIENTIFIC EQUIPMENT

GEOPHYSICAL SCIENTIFIC EQUIPMENT

NON-SEISMIC SYSTEMS

General
Raytheon echo sounders: 3.5 Khz (2 KW) and 12 Khz (2 KW)
Geometrics G801/803 magnetometer/gradiometer
Bodenseewerk Geosystem KSS-31 marine gravity meter
E.G. & G. model 990 side scan sonar
Nichiyu Giken Kogyo model NTS-11Au heatflow probe

Navigation
Differential GPS System

Magnavox T-set Global Positioning System
Magnavox MX 1107RS and MX 1142 transit satellite receivers
Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers
Magnavox Differential GPS System
Arma Brown and Robertson gyro-compasses; plus Ben paddle log
Decca HIFIX-6 radio-navigation system, modified for long range operations

SEISMIC SYSTEM CONFIGURATION FOR DEEP CRUSTAL SEISMIC REFLECTION PROGRAM IN AREA "A' OF THE ZONE OF COOPERATION, TIMOR SEA

The anticipated recording parameters to be used on the deep crustal seismic survey in the Zone of Cooperation are as follows.

SEISMIC SYSTEM

Streamer
Fjord Instruments transformerless.
3600 to 4800 m seismic cable.
144 to 192 seismic channels.
group interval 25 m.
depth 10m nominal.

Field Data
8 hz - 256 hz passband
2 ms demultiplexed
up to 15 sec record length
nominal 18.5 to 20 second shot rate

Seismic data supplied in SEG-Y format, special floating point format, 4 bit binary exponent, 12 bit mantissa. Conversion routinessupplied.

Energy Source:
16 x 150 cu.in. HGS sleeve gun array (2 arrays)
16 x 160 cu.in. HGS Mod III airgun array (2 arrays)
Gun depths 5 to 15 metres, spacing 0.5 metres

SEISMIC ACQUISITION SYSTEM (GENERAL)

Seismic cable:
Fjord Instruments, transformerless coupling
Maximum of 288 seismic channels, 12 auxiliary channels

10 Teledyne T-1 hydrophones per 6.25 metre group
Nominal sensitivity 20 Volts/Bar for standard group
Oil blocks to reduce low frequency noise
6.25, 12.5, (18.75), and 25.0 metre groups available
192 seismic channels,
Maximum towable length 6000 metres,
4800 m available

Energy Source:
5 x 80 cu.in. SSI S-80 watergun array
Gun depths 3 to 5 metres, spacing 2.5 metres
16 x 150 cu.in. HGS sleeve gun array (2 arrays)
16 x 160 cu.in. HGS Mod III airgun array (2 arrays)
Gun depths 5 to 15 metres, spacing 0.5 metres
Gun groups separated by 2.5 metres
Various gun groupings available
Configured as 6, 5, 3, and 2-gun groups
Usually fired as 4, 3, 2, and l-gun groups
Compressor capacity 1200 scfm nominal at 2000 psi

RecordingParameters:
Low noise charge-coupled preamplifiers
Preamplifier gain from 1 to 128 in 6 dB steps
Maximum of 320 channels including seismic and auxiliaries
LC filters 4, 8, 16, and 32 Hertz at 18 dB/octave
HC filters 90, 180, 360 and 720 Hertz at 140 dB/octave
Sampling rates of 0.5, 1, 2, and 4 millisecs
Record lengths from 2 secs to 20 secs
SEG-Y recording format with extension
IFP operating at 200 khz with special floating point format
Data recorded as 4-bit binary exponent and 12-bit mantissa

Other:
Reftek receiver and sonobuoys
Yaesu sonobuoy receiver and Spartan SSQ-57A sonobuoys
Raytheon echo sounders: 3.5 Khz (2 KW) and 12 Khz (2 KW)
Geometrics G801/803 magnetometer/gradiometer

CONTINGENCY SEISMIC SYSTEM CONFIGURATION FOR HIGH RESOLUTION PROGRAM

The anticipated recording parameters to be used during any contingency on the high resolution seismic survey in the Zone of Cooperation would be as follows.

Source

5 X S80 water guns

80 cu in per gun (air)
2000 psi air pressure
gun spacing 2.5 metres
gun depth 3 to 5 metres.

Streamer
Fjord Instruments transformerless.
10 Teledyne T-1 hydrophones per 6.25m group.
900-1200 m cable, 144 seismic channels,
group interval 6.25-12.5 m.
depth 5m nominal.

Field Data
8 hz - 256 hz passband
1 ms blocked multiplexed
up to 3 sec record length
nominal 4.85 second shot rate
shot interval 12.5m for 36 fold CDP coverage (at 6.25 m group interval)
Shot-to-group 1 offset : 100 m if achievable

Seismic data supplied in SEG-Y format, special floating point format, 4 bit binary exponent, 12 bit mantissa. Conversion routines supplied.

High Resolution Source Rationale
BMR has been developing a seismic energy source specifically for use in high resolution surveys. The energy source is built around five S-80 waterguns of 80 cu.in. capacity manufactured by Seismic Systems Incorporated of Houston USA. The primary objective is to have an energy source that has a variable output energy level but an invariant power spectrum and signal waveform. By using multiple waterguns separated by more than their interaction distance, we can use from one to five guns without changing the output signal shape. It also has the advantage of a "clean" signal without bubble pulse that might obscure near-surface detail in the field. These advantages are considered to outweigh the disadvantage of a non-minimum phase energy source. Preliminary tests of the watergun array have been encouraging. Reliability and repeatability of individual gun signatures has been good.

GEOCHEMICAL SCIENTIFIC EQUIPMENT

Water Column Geochemistry

The Direct Hydrocarbon Detection (DHD) method continuously analyzes C_1-C_8 hydrocarbons within seawater. Thermogenic hydrocarbons migrating up faults from source rocks and/or hydrocarbon reservoirs debouch into the seawater at the seafloor, producing higher concentrations of light hydrocarbons within the water column. These seep gases have molecular compositions that are distinctively different from that of the biogenically-produced hydrocarbons which are mainly produced by *in situ* processes in seawater. If the hydrocarbons are present in sufficient amounts, the molecular composition of the thermogenic hydrocarbons may be used to infer whether the primary source of the seep was oil, condensate or dry gas.

The method used on the RV `Rig Seismic' is as follows. Seawater is continuously delivered into the geochemical laboratory onboard the ship via a submersible fish (which is towed approximately 10 m above the seafloor). The seawater is 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 (THC) are measured every thirty seconds, light hydrocarbons (C_1-C_4) are measured every two minutes and C_5 to C_8 are measured every 8 minutes. These data, as well as fish altitude (above the seafloor), the depth of the fish, hydrographic (temperature and salinity) and navigation data are recorded on computer. All these data are recorded and displayed continuously so that any hydrocarbon anomalies in the water column can be quickly recognised and additional measurements can be made when appropriate. Detection sensitivity is approximately 10 parts per billion in the stripped headspace sample. At a ship speed of 4 knots, the measurement of THC is made every 70 m, C_1-C_4 every 250 m and C_5 to C_8 every 1400 m.

GEOLOGICAL SCIENTIFIC EQUIPMENT

Geological and geochemical equipment which could be used during contingency geological coring operations:

Australian Winch and Haulage deep-sea winch with 10,000 m of 18 mm wire rope and a hydrographic winch with 4000 m of 6 mm wire rope

Gravity, piston, box and vibracores
Grab sampler
Pipe and rock dredges
Niskin bottle water samplers
Underwater camera

Sediment And Porewater Geochemistry

Flow injection analyser

UV-VIS spectophotometer

Gas chromatographs

Enclosure 1. Proposed deep crustal seismic reflection and water column geochemical program within the Zone Of Cooperation, Timor Sea, northwestern Australia

PROPOSED BMR DEEP CRUSTAL SEISMIC AND GEOCHEMICAL PROGRAM
ZONE OF CO-OPERATION