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Vulcan Sub-Basin, Timor Sea
Survey 97

High Resolution Seismic Reflection Profiling and Direct Hydrocarbon Detection
(Vulcan I)
Post-Cruise Report

Project 121.19

G.W. O'Brien & J.F. Marshall

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Executive Summary

The objectives of Project 121.19 were: ***To understand the deep crustal architecture, the structural reactivation processes and the mechanisms of hydrocarbon generation, migration and entrapment within the Vulcan Sub-Basin, Timor Sea.***

To achieve the aims of the project, two surveys (Vulcan I & II) were conducted between October and December 1990. This report summarises the results of the Vulcan Sub-Basin I Survey (Survey 97), which focussed on the high resolution seismic and geochemical component of Project 121.19 (i.e. the structural reactivation, hydrocarbon generation and migration theme).

In addition to the Timor Sea program, a small experimental sub-program was carried out in the Dampier Sub-Basin, Western Australia, in conjunction with Woodside Petroleum. This program was located in the vicinity of the Angel, Cossack and Wanea petroleum discoveries and formed part of the BMR research theme which is examining the history of Cainozoic fault reactivation on the Northwest Shelf and in the Timor Sea. Details of this program are provided in BMR Record 1991/67.

R.V. *Rig Seismic* departed from Fremantle, Western Australia, at approximately 1830 hours on Thursday, October 18, 1990 and steamed to the northern Dampier Sub-Basin to carry out a joint BMR-Woodside high resolution seismic investigation in the Dampier Sub-Basin (WA-28-P). The ship arrived in the vicinity of the Angel gas field on October 22, with the study being completed on October 28, 1990. A total of 490.5 km of high resolution seismic and 530.6 km of DHD data were acquired in the Dampier Sub-Basin. All the objectives of this sub-program were successfully completed.

The ship sailed north to the Timor Sea, arriving in the southern Timor Sea on October 31, 1990. The seismic and DHD systems were then tested and data acquisition began at 0800 hours, October 31, 1990. Over the next two and a half weeks, 34 dip lines and 10 strike lines were acquired between the southernmost Vulcan Sub-Basin and the Sahul Syncline to the north.

Both the seismic and DHD systems performed well. There were very low noise levels on the seismic cable because of the combination of a new and well-balanced cable and generally very calm sea-states. The record length was 2.5 seconds, with penetration typically to greater than 1500 msec. The survey ended at 0800 hours on Saturday, November 17, the seismic cable was retrieved, and the ship transited to Darwin, Northern Territory, arriving at 0800 hours on Monday, October 19, 1990. A total of 2730 km of seismic/DHD data (44 lines) were collected in the Timor Sea.

The Timor Sea program achieved most of its objectives. The seismic data should, when processed, allow a much better understanding of the nature of the fault reactivation processes in the area. In addition, strike lines run along the Londonderry High show that near-vertical faults appear to correspond with the position of transfer faults which have been inferred from our interpretation of BMR's Timor Sea aeromagnetic data.

The geochemical program identified a number of significant hydrocarbon anomalies in the area. The anomalies fell predominantly into two groups. One group was located over, and to the north-east to south-east of the Skua Field, while the other group was associated with transfer faulting, and a major aeromagnetic high, on the edge of the Vulcan Sub-Basin, south-east of Montara 1.

Unfortunately, no side-scan sonar or sediment geochemical data were collected on the cruise. The side-scan sonar malfunctioned at the beginning of the survey and could not be made serviceable. No sediment sampling was possible because of time constraints.

Introduction

The discovery of significant hydrocarbon accumulations in the Jabiru, Challis, Skua, Oliver, Talbot and Montara fields wells has substantially upgraded the prospectivity of the Timor Sea region (Figure 1). However, this initial success, which led to vigorous exploration activity in the area, has been followed by period of very low reward for explorers. In order to assist the exploration effort and improve exploration efficiency in this region, the Division of Marine Geosciences and Petroleum Geology (Bureau of Mineral Resources) has, as part of its Continental Margins Program, carried out two research surveys within the Timor Sea. These projects have been designed to improve the assessment of the area's prospectivity by acquiring and integrating data sets which compliment, rather than duplicate, the data typically acquired by the petroleum industry. High resolution seismic reflection and direct hydrocarbon detection (DHD) water column geochemical data were acquired during Vulcan Sub-Basin Survey I, whereas deep crustal seismic reflection data were acquired during Vulcan Sub-Basin Survey II. These data are to be integrated with a large regional aeromagnetic data set which was collected by BMR over the entire Vulcan Sub-Basin and surrounds in late 1989 (Wellman & O'Brien 1991).

This report summarises the results of Survey I, in which high resolution seismic reflection and direct hydrocarbon detection water column geochemical data were collected.

The aim of Survey I was to obtain an improved understanding of:

- The timing of structural development relative to hydrocarbon generation and migration. This is to be addressed by integrating the high resolution seismic data and DHD geochemical data with ongoing geohistory and maturation modelling studies.

- The relationship between structural reactivation and hydrocarbon migration and trapping mechanisms.

Study Area, Regional Geology And Tectonic Evolution

The Vulcan Sub-Basin is located within the Timor Sea on the far northwestern Australian margin and lies approximately half-way between the Kimberley Block and Timor (Figure 1). It is presently one of Australia's most active petroleum exploration areas, with a number of significant oil discoveries, including the Jabiru, Challis/Cassini, and Skua fields. It is flanked by two major elevated blocks, the Ashmore Platform to the northwest and the Londonderry High to the southeast (Figure 1). The Vulcan Sub-Basin itself is sub-divided into a series of NE- and ENE-trending, asymmetric sub-grabens (Figure 2) which are separated by intra-graben terraces (Patillo and Nicholls, 1990).

The tectono-stratigraphic evolution of the Vulcan Sub-Basin, the Ashmore Platform and the Londonderry High has been sub-divided into three megasequences: the pre-rift, the syn-rift and the post-rift megasequences (Patillo and Nicholls, 1990). The pre-rift megasequence consists of latest Permian to Middle Jurassic sediments and is truncated on a regional scale by a late Callovian Unconformity. The overlying syn-rift megasequence, which is largely restricted to the Vulcan Sub-Basin 'proper', is comprised of late Callovian to early Valanginian silici-clastics. Intense faulting during this time introduced a strong E-NE orientation to the Sub-Basin. Syn-rift sedimentation was terminated in the Valanginian by a period of uplift and substantial erosion:- erosion was particularly pronounced on the terraces and horsts within the Vulcan Sub-Basin and on the flanking platforms such as the Londonderry High. Sands immediately subcropping the Valanginian Unconformity host the major hydrocarbon accumulations in the Timor Sea, and range in age from Late Jurassic at Jabiru to Middle to Late Triassic at Challis. Overlying (post-rift megasequence) claystones provide the seal. The variability in the age of the reservoirs reflects the highly variable amount of erosion of the fault blocks during the Valanginian.

The post-rift megasequence overlies the Valanginian Unconformity, and consists of sediments ranging in age from late Valanginian to Quaternary. This sequence reflects the thermal subsidence phase with the development of a passive continental margin, the sequence becoming progressively more marine with time. During the Late Miocene, the northward-moving Australian plate collided with the Eurasian plate, introducing a compressional regime in the Timor Sea. This collision reactivated many of the rift faults and introduced east-northeasterly fault trends, particularly within the post-rift megasequence in the more northerly part of the Vulcan Sub-Basin, where the collisional effects are most pronounced, and ENE-oriented faulting is intense. The collision also resulted in the formation of the Cartier Trough and mobilised the Palaeozoic salt which is present within the Paqualin and Swan Grabens (Figure 2; Patillo and Nicholls, 1990).

Objectives

Survey 1 had several objectives, which fall into three broad categories:

- To investigate the processes of structural reactivation associated with collision and foreland basin development along the northern margin of the Australian craton using high resolution seismic reflection profiling. In particular, to better understand how these processes have controlled the entrapment of hydrocarbons and, in some cases, how reactivation has resulted in the breaching of hydrocarbon reservoirs, as occurred at Avocet 1A (Whibley & Jacobson, 1990). Very high resolution seismic data should allow the relationship between the shallower post-rift faults and the deeper syn- and pre-rift faults to be better delineated. For example, the post-rift faults often step out in front of the deeper syn/pre-rift faults, which caused problems in the Skua Field (Osborne, 1990).

- To obtain closely-spaced high resolution seismic reflection data over parts of the Vulcan Sub-Basin in order to better understand the factors controlling the short wavelength magnetic anomalies which have been previously defined (Wellman & O'Brien 1991) by the BMR aeromagnetic survey conducted in 1989. These magnetic anomalies consist of both northeast-trending and northwest-trending features. The northeast-trending magnetic trends closely match the normal fault trends at the prospective Valanginian Unconformity horizon, whereas the northwest-trending features correspond with offsets in the major northeast-trending anomalies (Wellman & O'Brien, 1991). The northwest-trending anomalies, which are probably due to the reactivation of either Mesozoic transfer faults or Palaeozoic normal faults, may have a major role in the entrapment of hydrocarbons in the Timor Sea, as most producing fields are located close to a northwest-trending fault, or its extension. As the northwest-trending faults have not previously been identified using seismic data, it is hoped that high resolution seismic profiling will clarify both their origin and their relevance to hydrocarbon entrapment in the Timor Sea.

- The Direct Hydrocarbon Detection method (DHD) has not been extensively used in Australia, and the majority of surveys that have been conducted are not publicly available. A small 'sniffer' survey conducted by InterOcean in the Timor Sea for BHP in 1989 falls into this category. The Timor Sea appeared to be a good location to test this method's usefulness as a remote sensing tool, as many of the faults extend all the way from the reservoir/source horizon to the seafloor. During Survey I, DHD data were acquired was over a complete range of structural styles within the basin. DHD lines were run over the following hydrocarbon discoveries:- Skua, Montara, Puffin, Oliver, Talbot, Keeling, and Pengana. This allowed the method to be 'ground-truthed'. Lines were also run over a large number of (as yet) undrilled prospects throughout the Vulcan Sub-Basin, in order to test the usefulness of the method as a predictive tool in petroleum exploration in the region. Other specific DHD investigations included:- detailed work in the vicinity of the Avocet 1A structure, which was an oil field that was breached during the Late Tertiary reactivation; regional lines over the western and central Cartier Trough; regional lines over the Ashmore Platform, regional lines over the Londonderry High. These regional lines may allow the relative gas versus oil prone nature of these areas to be determined, particularly when integrated with ongoing geohistory and maturation studies.

Cruise Summary

R.V. *Rig Seismic* departed from Fremantle at approximately 1830 hours on Thursday, October 18, 1990 and steamed directly to the northern Dampier Sub-Basin to carry out a joint BMR-Woodside experimental high resolution seismic study in exploration permit WA-28-P. Complete details of this aspect of the Vulcan I survey are provided in O'Brien (1991) and O'Brien et al. (1991b), and will not be further discussed here. A total of 490.5 km of high resolution seismic data and 531 km of water column geochemical data were acquired in the Dampier Sub-Basin and all objectives were achieved.

At the completion of the Dampier Sub-Basin work (Sunday, October 28, 1990), the ship then sailed north to the Timor Sea, arriving in the southern Timor Sea, approximately 30 km southeast of Montara 1 exploration well, at 0230 hours on Wednesday, October 31, 1990. The seismic and DHD systems were then tested and data acquisition began at about 0800 hours (October 31) with the acquisition of survey line 97/025. Over the next two and a half weeks, 34 dip lines and 10 strike lines were acquired between the southernmost Vulcan Sub-Basin and the Sahul Syncline to the north (Figure 1 & 3).

Results

2730 line km of high resolution seismic reflection data with a 2.5 second record length were recorded along 44 survey lines (Figure 3). The lines were designed to tie as many wells and prospects as possible, while also acquiring a regional grid. Table 1 provides the details of the seismic lines acquired.

2730 line km of direct hydrocarbon detection (C_1-C_8^+) data (DHD) were acquired (Figure 3). The DHD data were collected simultaneously with the high resolution seismic data, allowing geochemical anomalies to be related to both seafloor and sub-seafloor geology. Table 2 provides the details of the DHD survey lines: these lines are generally slightly longer than the seismic lines, as DHD acquisition generally began slightly before, and continued after, seismic acquisition on any individual line.

High Resolution Seismic Reflection Profiling

The high resolution seismic system generally performed well during the survey, with relatively little downtime during actual lines. The short cable was very stable with low noise levels, and the configured watergun array achieving penetration to greater than 1500 milliseconds. With a 2.5 second record, it was considered that most lines, other than those in the Cartier Trough, would be capable of imaging the entire post-rift sequence down to the Valanginian Unconformity. While the monitors on board only gave a 1.5 second (TWT) display, it was felt that both syn- and pre-rift sequences were likely to be encountered beneath the Londonderry High and the flanks of the Vulcan Sub-Basin. While multiples were a problem in interpreting the monitor sections, in most cases it was possible to make out the Late Miocene, Oligocene/Eocene and base Paleocene unconformities. Resolution of Cretaceous or Jurassic events was generally difficult from the monitors. The numerous ties to wells made it relatively easy to pick these major post-rift events from the monitor records.

The seismic data should allow, when processed, the accurate recognition and definition of the reservoir horizons (and associated facies) over much of the Vulcan Sub-Basin. It should also provide a much better understanding of the nature of the fault reactivation processes in the area. In addition, strike lines run along the Londonderry High show that near-vertical faults appear to correspond with the position of transfer faults which have been inferred from our interpretation of BMR's Timor Sea aeromagnetic data. Integration of both the high resolution and deep crustal seismic data with the aeromagnetics should provide major advances in our understanding of basin evolution and the controls on hydrocarbon entrapment.

Because many of the syn-rift faults have been reactivated during the Miocene collisional phase, they can be readily discerned on the monitors. Commonly, these faults crop out on the seafloor or else terminate just below it. While no "hourglass" structures, which are a particular feature of the Vulcan Sub-Basin, could be observed on the monitors, it was possible to observe the graben-like features that are normally associated with the tops of these structures. Most faults, however, are down-to-the-basin features, with generally only a small amount of throw in the upper part of the section. This type of faulting is best displayed in the Cartier Trough, where growth faults gradually step down on the edges of the trough, whereas towards the centre of the trough the sediments are generally undisturbed.

It appears that the seismic reflection data will be of high quality when processed, and should allow the stated survey objectives to be achieved.

Direct Hydrocarbon Detection

The DHD equipment performed well during the survey with very little down-time. A total of ten distinct geochemical anomalies were detected during the program. These anomalies are summarised in Table 3. The anomalies fell predominantly into two groups. The first group was centred over and, particularly, to the north-east (towards the Birch 1 exploration well) and to the south-east (towards the Swift 1 well) of the Skua Field. The second group was located approximately 35 km south-east of Montara 1. This second grouping was associated with a large transfer fault (as delineated by aeromagnetics: Wellman & O'Brien 1991) and a significant aeromagnetic "high" on the edge of the Vulcan Sub-Basin. The geochemical anomalies are typically moderately subtle, and are characterised by a significant ethane enrichment relative to methane. The geochemical results are fully discussed in O'Brien et al. (1991a).

Sediment Sampling And Side-Scan Sonar

No side-scan sonar or sediment geochemical data were collected on the cruise. The side-scan sonar malfunctioned at the beginning of the survey and could not be made serviceable, while sediment sampling was not possible because of time constraints.

Systems Performance: Vulcan Sub-Basin I

System Evaluation By Mr E. Chudyk

Tape Drives

The tape drives performed at a less than excellent level. Several connectors have now been replaced as have most of the interconnecting cables. I think that some of the parity errors are being caused by worn capstan wheels. I have observed a higher than normal amount of phase jitter between tracks while checking the head alignments. This phase jitter is worse on drives which display higher error rates; I have asked for 2 replacement capstan wheels from Minima. I hope to replace the capstan wheels and a re-align of the capstan motors and tape heads in Darwin. So far three of the drives have new screw down catches, these should stop some of the problems caused by drives opening unexpectedly.

Three used capstan wheels arrived in Darwin; two of which appeared to be in better condition than the ones on the drives. The replacement and re-alignment of one capstan wheel completely cured its phase jitter problem. Replacement and re-alignment of the remaining problem drive improved, but did not completely cure, the phase jitter. One possible reason for my lack of success on the second drive may have been the inferior condition of the replacement wheel. After considerable fine tuning all four drives were working satisfactorily before the next survey left. I recommend that all the Shamrock tape drive capstans on the ship be replaced and the drives aligned. Since the Shamrock drives need a fair degree of maintenance I recommend that at least two days be allocated to this task, one either side of a seismic cruise.

Magnetometer

The magnetometer started the survey with about 3-4 nT of noise; the condition of the signal then deteriorated until the Geometrics DC power filter was re-installed. The final noise level on the mag. was about 2 nT which is not to bad considering that the offset from the ship was less than optimum; however further improvements are needed. The magnetometer winch control box is about due to be replaced, hopefully a more easily opened and closed variety will be selected.

Gravity Meter

The gravity meter caged once on the survey. Again the problem was the cage-operated pot on the sensor unit. The pot was lubricated and seems to have functioned well ever since. However, the meter had to be switched off during repair so the gravity ties will not be of a lot of use.

Clocks

During the initial stages of the cruise, the DAS clocks performed poorly. Jim Wattman has designed a functioning interface between the clocks and the EPC's which seems to have fixed both the clock problems and the EPC timing lines. The clock comparators did not work for most of the survey: I have found the most likely cause to be the high noise level and erratic pipping of the Omega receiver, (pips occur at the 9 and 5 second marks). The noise on the Omega receiver may have a common source with that found on the magnetometer, Magnavox sonar doppler and paddle log. Further investigation is required.

12 kHz Echo Sounder

This echo sounder has not function properly during the cruise. Roger replaced the old fan in the correlator box and made a few other repairs which seemed to fix it. However, after functioning for a few days, it failed again. Work on the problem is continuing.

3.5 kHz Echo Sounder

The 3.5 kHz echo sounder worked extremely well for the entire survey. The recorded water depths should require a minimum of processing as the water bottom was locked in the digitizing gate for nearly the entire cruise. Virtually no sub-bottom penetration was detected during the cruise: the most probable cause of the lack of sea floor penetration is the hard bottom throughout survey area. I am still not convinced that the 3.5 kHz echo sounder will sub-bottom profile in shallow water: a shallow water test should be undertaken at a location where the thickness of sea floor sediment is known.

Sonar Dopplers

The sonar dopplers worked reasonably well on the cruise, except for the Magnavox, which had its normal difficulty tracking down slopes. A systematic dead reckoning error was observed on the navigation plotter; after the navigation data is processed we should have a good estimate of what correction to apply. The Magnavox began picking up some noise, particularly in deep water, towards the end of the cruise.

Gyros

The gyros and gyro-log interface worked well on this cruise. Only the occasional 1 - 2 degree correction was needed to keep the interface box tracking the gyro headings.

Paddle Log

The pad paddle log output has been disconnected at some time in the last 2 months. Re-connection causes very noisy speed values to be displayed. We are unsure as to the cause of this problem; it could be the problem is in the gyro-log interface box which was modified prior to this cruise.

Communications

Communications on Survey 97 were some what hampered by an erratic, if not broken, stenophones. Stenophone controllers that are U/S., particularly the one the seismic desk, should be repaired before the next cruise. Radio communications to shore were generally good except towards the end of the cruise, when the frequency of atmospheric disturbances increased.

Amplifiers

The 144 seismic amplifiers performed reasonably well, though several calibrations were required during the survey. The control cards and control box however were a major source of problems. Amplifier gain, filter and input state on boxes 3 and 4 dropped out on numerous occasions. The E.S.U. personnel believe they know the cause of the drop-outs, though the connections to the cards in the control, (auxiliary), box remain a mystery. The control box wiring should be completely check. In addition, repairs the oscillator circuit (which now refuses to work with filter settings of 8-64) are necessary. The status of the spare amplifiers, including those in the auxiliary channels is currently unknown, I have had a few attempts at calibrating the auxiliary channels but have given up because they inject noise into the rest of the system.

Gun Controller

The gun controller seemed to work successfully on the cruise. However, we did not have the capabilities to monitor the correctness of the firing times. Two modifications were carried out by E.S.U. during the cruise; the first was to increase the gain of the water gun sensor amplifiers and the second changed some capacitors (on the input???). These modifications appeared to change the performance of the controller and will have to be investigated before the next water gun survey. The weak part of the gun controller was the shot sensors used, see next section, complicated by the lack of rigourous testing of the controller prior to use on the survey. I hope further improvements can be made before this system is used again.

Source Sensors

The source sensors were a major source of concern during the cruise. Their high failure rate caused the retrieval of the gun string more often than would have been otherwise necessary. The output level of the sensors is not strictly related to capacitance, which makes fault-finding more difficult and results in the unnecessary stripping of guns. In short, the use of calibrated hydrophones to control the shot instant of the water guns appears to be a very expensive process. There are currently enough second-hand source sensors on the ship to equip the sleeve gun arrays should new hydrophones be unavailable. The calibration, frequency response and life expectancy of these used phones is, however, completely unknown.

Before installation on the water gun array all source sensors were tested using the following method:

1) a source sensor was selected to be the calibration source

2) the calibration source was placed in a beaker of water and connected to a BWD mini-lab

3) the mini-lab oscillator output was amplified using the BWD,s operational amplifier

4) oscillator output was set to sine wave and the level increased until clipping occurred

5) the level was then reduced slightly and the output changed to a square wave at 100 Hz

6) the sensor under test was then placed in the beaker and connected to CRO in differential mode

7) the peak to peak signal was then read of the CRO screen and recorded.

8) values of 60 mV P-P were consider very good, ie. brand new

values of 40-50 were considered O.K.

values of 30 or less were rejected

9) tap tests were carried out however it was found that a good response to tap did not necessarily correspond to a good hydrophone, ie. possibly no high frequency response

10) as mentioned earlier capacitance tests were also conducted however they give only a crude approximation of the output performance eg.. 3 phones had there rated capacitance but almost no output.

At the present time, the use of a driven and a receiving hydrophone appears to be the best method for determining the output response of source sensors. New sensors respond quite well to this method and show an essentially flat response from about 30 to 500 hertz; older sensors tend to respond better at the low end of the spectrum than they do at the top. I recommend that used sensors be tested at several frequencies with attention being given to the high end of the spectrum.

During the final stages of the survey the amount of friction tape on the shot sensors was doubled: this seemed to increase the time between sensor failures. However, since the original thickness of tape showed no sign of wear or damage, I am not sure why the increase in life expectancy should have occurred. The use of more robust sensors should generate considerable cost and man-power savings during a high resolution cruise.

Source Signature Recording

If source signatures are to be recorded accurately, I recommend that the following procedure be followed.

1) check the sensor output as described above, write down there serial numbers and sensitivities and capacitances

2) install the most sensitive hydrophone at the centre of the largest group of guns, or alternatively over one of the end guns of a water gun array, ie. the source sub-group with the highest output.

3) select a reasonable amplifier gain, probably about 8, the filters set the same as the amplifiers

4) with the guns firing adjust the auxiliary channel attenuator pot such that the maximum signal level is well below, probably about 1/2, the clip level

5) measure the resistance of the attenuator and then set all the attenuators to this value

6) log all the relevant details about the source sensor geometry, hydrophone sensitivity, and the attenuation factor for each of the source sensors.

7) after recording the required number of signatures the gun hydrophones should be removed and re-tested to ensure their sensitivity has not changed

The procedure listed above should allow a un-clipped sensor signals to be recorded and facilitate true amplitude recovery of the near field source signature.

Array Depth Detectors

Are far as I have been able to determine, only two D.T.'s where replaced on the whole survey; one of these due to a fault in the cable bundle. By and large, the D.T.'s where very stable and only needed minor, +-.1 or.2 meters, adjustments even after prolonged spells of shooting. How well the gun controller collected this information is unknown. This failing should be improved in a later model.

Water Gun array depth

Although no changes were made to the array towing system from the trials, the array refused to run flat. The initial depth variations were about +/- .6 of a meter. The tethering cable was pulled in a meter which reduced the variation to about +/- .5 meters; no further improvement in towing depths could be made. Buoy number 3 was the chief cause of the uneven gun depths; for some reason this buoy continued to ride low in the water for the entire survey. If we intend to improve the towing characteristics of the water gun array we may have to use bigger buoys or ones with a different shape.

I recommend that we replace buoy number 3 with the next bigger size (A7 I think). This change should flatten the centre of the array and reduce the depth variation to +/- .25 meters.

Syntron Cable Levellers

The cable leveller worked very well all cruise, with only one set of batteries being needed for the Vulcan Sub-Basin segment. We are still following the practice of wrapping the bird rings in foam as a precautionary measure in an attempt to minimize skin creases. If the cable is to be stored for prolonged periods, it may prove prudent to wrap the connectors as well. This point is, however, subject to discussion. It is very important that the birds be washed in fresh water if they are to remain onboard. Each bird should be disassembled, inspected for damage and sprayed with CRC before re-assembly and storage. Much time and effort will be saved if proper care is taken of the depth levellers at the end of a cruise.

Cable Balancing

The 900 meter cable seems well balanced with 2 kgs. of lead per section, this gives a wing angle of about -6 degrees for the central sections and about -3 for the front and rear sections. The original calculations I did using the wing angle velocity data from the Syntron book indicated 6 kgs of lead would be required to balance the cable; we tried 5 kgs but this was still about twice to much. The long cable will probably need closer to 3 kgs than 2, especially if its going to be towed at 4 knots, not 5.

All in all the Syntron method seems to be out by at least 50 %, that is 50% heavier than required; (calculation error on my part I forgot to divided by 2 i.e. there are about 2 sections per controller.) Lead should be placed on the cable such that up to 5 kgs could be put on without resorting to double sheets eg.. one sheet at the centre one sheet at the end of the 3 group from the connectors and one sheet 3 groups from the centre. We have placed the sheets just before the rear oil blocks on the groups. This position should minimize the effects of turbulence on the following group while not adversely effecting the forward group. All lead is attached using the standard method taking care not to leave sharp edges on the sheets. In the past we have found the use of half kg lead weights to be more trouble than its worth I am yet to be convinced the added turbulence caused by multiple half kilo sheets is worth the reduction in wing induced noise.

Tail Buoy

The stability of the tail-buoy has been markedly increased by the re-introduction of a chain towing bridle. There is still a problem with the flashing light; the current model lasted for the whole of the Vulcan Sub-Basin segment on one set of batteries. However it did switch itself off for a week or two to conserve its strength for final retrieval. Hopefully someone will find another type which is slightly better.

Leakage Detection

The leakage test facility of the DSS 5 has detected one fault thus far. I guess that makes it the only fault so far. It is very straight forward to use and should show salt water intrusion quiet well. There are three types of leakage +/-, +gnd and -gnd, each of which tell you something different about the fault. I think +/- leakage is the best indication of salt-water, while the other two probably indicate wiring or pin damage more successfully. The last leakage tests conducted on both the 900 m and 3600 m cable showed all resistances were greater than 1 mega Ohms. The cable did not suffer one fish bite on the cruise; I wonder if the leakage caused the old streamer to radiate enough noise to attract sharks et al.

Amplifier Tests

During the final transit a number of amplifier test were undertaken. Using the same parameters as the survey ie 8-256 Hz filters, 1 ms sampling and a test gain of 256, only channel 49 was found to be somewhat faulty,; this problem recurred during the survey and seems to be due to cabling to the Phoenix. The filter cut-off frequencies were also re-checked and found to O.K. The tests were repeated with the filters set to 8-128. This time, channels 107 and 108 were faulty, indicating a problem in the high cut filter section. An attempt was made to run the tests with 8-64 filters; however, the internal oscillator would not work at 32 Hz. The test were all repeated using the DSS 5 oscillator with comparable results except for a frequency of 32 Hz. were channel 73 showed up as faulty. The amplifiers were then tested with their inputs shorted; channels 104 and 119 were intermittently noisy and will require further investigation.

Cable Connectors

The new Geco streamer cable has much more complicated connectors than the old Teledyne cable. They require two people to connect them together. There are close to three times as many pins as in the old streamer, which makes them about 9 times as likely to go faulty. Consequently, extreme care is required when splitting and re-coupling the sections. In Geco's cable manual, they talk about allen screw extractors and broken allen screws; to help eliminate this problem the allen screws should be silicon-greased before they are screwed into the connectors.

All O-rings, nitrile and nylon must be inspected including those on the filler screws. It is safest to replace all these type of seals when re-connecting the cable. Use only the allen key T-bar to screw up the allen screws, they squeak when there tight; do not over tighten the two filler valves in the centre as this can cause the internal O-rings to split. Use lots of Norwegian CRC to get all the moisture out of the plugs. Compressed air should be used to blow all the sea water off the connectors before opening, special care should be taken around the screw holes etc. There has been a suggestion that the outside of the connector be sprayed with CRC before opening however this is getting a bit excessive. Jim Wattman has made up some screws which fit through the filler valve holes and act as guides to keep the connectors properly aligned during re-connection. I think that these will be quiet useful.

Systems Report By Mr Frank Brassil

Navigation

Differential GPS

The primary navigation system was the Magnavox 4810 DGPS system. This was installed by Magnavox at the beginning of the cruise, with a shore station 600 km away at Charles Point near Darwin. A separate report describing use of the DGPS system has been written. Summary tables of use of the DGPS over the cruise have been compiled and are attached. The availability of DGPS varied between 50% to 80% per day. There were two causes for it not being available: transmission problems from the shore station and poor constellations. The two are not entirely independent variables because the remoteness of the shore station meant that in periods when the constellation was thin, the separation meant that the time when both receivers could see the same satellites was reduced. The performance problems tended to be worse on weekends, and this is believed to be related to adjustments being performed to the satellites by the US.

When working well, the DGPS is an excellent navigation system for BMR's purposes. It consistently kept the ship accurately on track, and the Transit Satellite fixes always came out exactly on line, which provided a re-assuring confirmation.

A qualitative but important measure of its performance is the response of the Bridge staff. The consensus from them was that when it was working well, it gave consistent readings for speed and cross course error, and the ship could be successfully navigated on track using only small adjustments to heading and pitch. This is intuitively what one would expect when the system is running smoothly.

When performance is poorer two things happen. Firstly, the variations in speed and cross course error become more severe, and secondly the system drops out of Navigation mode to Tracking Satellites mode for periods of a couple of minutes and the DAS reverts to dead reckoning. The bridge crew tended to ignore rapid course changes from the dead reckoning and to maintain the existing course and speed. Typically, the system would come back after a couple of minutes and the ship would show no significant loss of position. If the system did not come back after a short period, the T-SET GPS system would be switched in and this would continue to navigate the ship. Jumps in course and speed would frequently accompany the change, which would settle down after a minute.

T-SET was an invaluable back-up to the DGPS. It proved to be more robust during periods of poor constellations, principally, I believe, because of the availability of clock aiding.

The DGPS is not without its idiosyncrasies. It it vulnerable to "going bananas", during which time the constellations seem acceptable, the radio seems to be providing constant updates and the T-SET remains demure but the system show absurdly high error values and will not navigate. It has been dealt with in a number of ways as outlined in the DGPS guide.

I recommend that DGPS continue to be used as the primary navigation system for RIG SEISMIC cruises. T-SET must be retained as the principal back-up system for the DGPS. Given the experience of this cruise, these two systems combined appear to provide an acceptable standard of navigation which is simple to operate and available virtually all the time. If the shore station was better located, the DGPS should perform better, and as time goes on, the constellation problems will diminish.

Radio Navigation

The HIFIX Radio Navigation system was also running during this cruise. There were two Shore Stations as follows:

Charles Point (Near Darwin)	**12^{0} 23'14.46"S**	**130^{0} 37'10.44"E**	**62 metres**
Troughton Island	**13^{0} 44'49.12"S**	**126^{0}8' 57.39"E**	**54 metres**

These values are on the WGS84 Spheroid.

Troughton Island was transmitting on slots 2 and 3, Charles Point was transmitting on slots 4,5 and 6.

After some difficulty, not least of which was the total unfamiliarity of the writer with Radio Navigation in theory or practice, it was determined that the transmissions on Slot 3 were not being handled correctly. The fault is probably in the HIFIX receiver. The system was switched to receive data from slot 2, and sensible values came in.

The following table lists the various channel identifiers:

HIFIX CHANNEL	HIFIX SLOT	LOCATION	DAS CHANNEL
A	6	Troughton Island	25
B	2	Charles Point	26
C	6	Troughton Island	27

No attempt was made to use the Radio Navigation to drive the ship, because, firstly, the GPS in its various forms was doing the job adequately, secondly, no one on board had sufficient experience and background and thirdly we understood that the HIFIX was being recorded for comparison with DGPS.

On a number of occasions, the HIFIX transmission failed owing to various problems at the shore stations including electrical storms, generator problems and refrigeration failures.

Some modifications were done to the HIFIX data acquisition program HIGET because the system as configured was collecting three channels, whereas previously it had been written to collect six.

The modifications made were as follows:

The program starts by attempting to decode each of up to six channels. If a channel does not contain data, then it normally contains question marks. The effect of these is to cause a formatter error. Further, live channels should be the first ones in the sequence.

The program determines which channels contain good and bad data, and writes a message to this effect on the DAS console which is, mercifully, a VT220 with printer in parallel. It then collects data on only those channels which it decides have good data. This is done to avoid wasting time decoding channels of garbage.

There is a nasty catch which one needs to be aware of and it is that if the highest numbered good channel goes bad, then HIGET will assume that the channel count has been reduced and cease decoding that channel. So, if you fiddle with the HIFIX box, you may inadvertently switch off recording of some channels. If this happens then HIGET can reset itself if the system BREAK flag is set - i.e., type in **BR,HIGET** at the system console or at the DAS operator's desk in response to an interrupt prompt. This is the equivalent to re-starting HIGET and the status of all channels will be displayed. Check to make sure what is being recorded is what is required.

It may be possible to hard wire the number of channels for a given cruise somewhere in the system and have HIGET complain if the channels go bad, but I will leave that to those with deeper insights into the system than I have.

The DAS System

The Data Acquisition System performed without significant problem, despite the very high data rate generated by the input from the 4810 DGPS. However, it would not tolerate much additional work. It was impossible to get the line printer to work while the system was recording data. attempts to re-configure it were unsuccessful.

A couple of VDUs failed and have been returned to Canberra.

The Teletype System Console was replaced with a VT220 and a small printer in parallel. This is a much more satisfactory arrangement.

The EPCs were in need of constant monitoring, and some repairs were necessary.

The small HP systems (HADES) ran without problems for acquisition of the HIFIX data, was a little fragile for the Depth Display in the geochemistry lab, and the Side Scan variation could not be made to work at all.

The PC display of ship's track on the Bridge is a great idea - a picture tells a thousand words. One for the navigator would be a very useful tool because it helps the navigator keep a clear picture of where the ship is. The scale could be substantially larger than the flat bed plotter. providing more detail about the current position.

The DGPS display needs to be relocated so it is in the navigator's line of sight. It would be advantageous to re-locate the RADIO, MODEM and EDAC. The MODEM and EDAC are important because the displays give a very useful guide to the quality and quantity of radio transmissions.

Seismic Cable

This was the first production survey in which the high resolution configuration of the GECO cable was used. The cable was configured with 144 seismic channels, each 6.25 m long, with one 50m stretch section at the front and one 50 m stretch section at the rear. Total cable length was 900 m.

The cable was weighed with 2 Kg of lead on each 100 m section, these being two 1 Kg sheets located at 33 and 67 m along the section. With this configuration, the cable had a consistently slightly positive buoyancy, wing angles on the depth controllers typically showing in the -3 to -8 degree range. The cable maintained its level very well indeed, sitting a constant 5 metres depth without any intervention from the instrument room.

The noise levels appeared to be very good, showing variations with sea state as the principal factor.

All 144 channels were live at the start of recording and remained live till the end of recording. The cable was deployed only once, and retrieved at the end of the survey. The depth controller batteries were adequate for this time.

This is an excellent cable, working well in practice and should be interfered with minimally.

Seismic Acquisition System

There were numerous problems with the acquisition system. The cable was connected to the amplifiers through a DSS-V conditioner. During the Woodside Co--operative part of the cruise, the line conditioner part of the DSS-V was by-passed because certain of the boards caused some bad channels. The by-passing was done on the advice of the Electronics staff who advised that the box did nothing except provide the facility for a leakage check. Following installation of correct boards after the completion of the Woodside work, all 144 seismic channels came good and remained good for the whole of the cruise. The recommendation is that the DSS-V is working well at present and should be left alone as much as possible prior to the commencement of the next cruise.

The amplifiers were major headache. After much work, 144 live and good amplifier channels were obtained. Initially no auxiliary amplifier channels were available. This changed for part of the cruise, but the amplifiers which were available proved to be unstable, and so they were disconnected.

Amplifier Bank 4 had a tendency to drop out without reason. With constant monitoring, the consequences were minimal because it could be reset by re-setting the GAIN and PASS parameters from the system console. Sometimes this had to be done numerous times before the system would return to its proper functioning.

The Phoenix appeared to work without problems.

The HP1000 computer and the Seismic Acquisition Software worked reliably. There were no crashes which could not be ascribed to operator error in some way or other. The most vulnerable area is the parallel interface printers. If one of them goes off line for any more than a brief period, then the system can crash. Replacement with buffered RS232 interfaces would obviously solve the problem, but given the imminent implementation if the VAX system, it is probably acceptable to put up with the problem for the interim.

The system recorded in Multiplexed Mode, recording 13 scans per output trace. The sample period was 1 millisecond, and the record length was 2500 msec. The SEG-Y magnetic tape header format and the instantaneous floating point format are given in Appendix 3.

The most serious concern was the tape drives, and the reports of parity errors which were constantly generated. These varied from a couple per tape to a report every shot. When the level became very high, the current output tape was replaced. However, it was never entirely satisfactory. Much effort went into attempting to minimise the problem, from being as scrupulous as humanly possibly about cleaning to moving boards and cables around, and changing drives and capstans. Nothing clearly related to the cause of the parity errors, but the problem seemed to diminish later in the cruise. Tape batches were essentially random. It was not related to any particular drive.

It is not clear that the problem will apply to reading the tapes. The parity error report is generated when the tape error flag is set on the F1000 interface. This indicates a problem with writing to the tape. It is not clear whether the problem was corrected by the ECC logic of the GCR format. The answer is probably that at least some of the errors will persist to the processing centre.

The drives pass all their internal diagnostics without any problem.

The screen on the Spit-Out CRO is badly burnt out.

Water Guns and Controller

The five water gun array used as the seismic source had two sets of problems. Firstly, the shot sensors were consumed at the rate of about two per day. This was the principal cause of problems with the array. The high attrition rate of the shot sensors is a cause for concern both in terms of cost and performance of the array. Some alternate means of detecting the shot which is more robust might prove to be more economical.

The secondary problem was the need for reasonably frequent maintenance of O-rings. The performance of these seemed to become more stable as the cruise progressed. It is not entirely clear whether it is better to service the guns at regular intervals, say 50,000 shots, and replace rings whether needed or not, or to wait till the gun shows problems and do something about it then. Towards the end of the cruise the latter strategy was forced upon us by the low state of O-ring stocks. This did not appear to cause too many problems.

The shot records show that guns would alter their firing delays randomly, and that the automatic adjustment system of the gun controller would then start to compensate. It is not clear whether this is related to the performance of the guns or the shot sensors.

The gun controller was vulnerable to transmission problems, and reported an auto-fire whenever there was a bad character transmitted to the controller. This resulted in excessive auto fire reports when in fact they were quite rare, though not completely unknown. Elimination of this problem would remove an ambiguity in the system.

Side Scan Sonar

An attempt to deploy this was made. Some problems with the deployment system were encountered. It is fairly cumbersome to put over the side, and would be impossible in a rolling sea to be confident of avoiding damage to the fish. Fortunately the weather was kind during this trip.

There was a short circuit in the cable near the connector on top of the fish which necessitated replacement of the connector.

The display system could not be made to work, and digital recording was not available, so this was a disappointment and use of the Side Scan was abandoned.

Summary

This cruise demonstrated that we can acquire large volumes of high quality, high resolution data. Some weaknesses in the acquisition system which should be alleviated by either maintenance or the upgrade of the systems have been frustrating, but ultimately the quality of the data, both seismic and navigation, will be the critical success factors for this cruise.

Mechanical Report By Mr Colin Green

Compressors

The cruise required the use of S80 water guns as the seismic source. The required amount of air could be supplied by running 3 compressors at low speed or 2 compressors at high speed. Generally, 3 compressors were run at a time. This ensured one back up unit was serviced and ready to operate in the event of a breakdown. The compressors performed very well and required little attention apart from the usual routine maintenance. All the valves were changed in unit no. 3 prior to the cruise. The 4th stage valves were changed in unit no. 4. and a pressure relief valve was replaced on 3 & 4. The new auto drain control box performed well. A water pipe to the 4th stage H/E cracked and was replaced on unit no. 2. Oil filters and anodes were changed at the end of the cruise.

Diesels

Unit no. 1 diesel shut down during the cruise for no obvious reason. Extensive investigation revealed a burnt out exhaust valve. A short time later, no. 3 shut down in the same fashion and again the cause was a burnt out exhaust valve.

The latter part of the cruise had to be completed using two compressors running at high speed. This put a high demand on the compressors and unit no. 2 failed due to clutch problems.

A new clutch plate was installed, the steel rim type, and the unit brought back on line.
Two replacement heads were ordered during the cruise so they may be ready to install prior to the next cruise.

Winches

The tugger winch no.4 wire was greased prior to the cruise. All maintenance was performed on the winches as required and no problems developed during the cruise. A solenoid controlled valve was replaced on tugger no. 4 prior to the cruise. Since no spare valve was available, it was taken from no. 1 tugger. Two replacement valves have been ordered.

Array

<u>Guns</u>

The water guns performed very well throughout the cruise and gave little trouble. Preventative maintenance was performed on the guns during the cruise as specified in the manual. However, for various reasons some guns failed before servicing was due and had to be overhauled. Some foreign material was found in one of the guns indicating an inline filter may be a good idea for future use.

The tow chain parted on two occasions, firstly due to a broken shackle and on the second occasion due to cavitation from the water blast. The first two gun hooks broke on separate occasions and were replaced with a more substantial type made of solid steel.

Bundle

The bundle clamp on no. 3 gun failed at the weld and a new one was installed. no other problems occurred with the bundle.

Buoys

One buoy rope was replaced due to chaffing but no other problems occurred. Split links were used instead of shackles to attach the ropes to the buoys and they proved very successful.

Suggestions

Following the success of the higher pressure in the buoys, I suggest the practice be continued in the future.

Other

The buoys were inflated to a much greater extent on this occasion as suggested by Ken. This proved to be a considerable advantage over the previous practice because of the fact that the buoy is arrested more firmly in the net thus reducing chaffing and abrasion of the net. The buoys and nets gave no trouble and require minimal attention. Ventilation of the compressor room has improved substantially since the installation of larger fans and ducting work. However, the temperature is still rather high for maximum efficiency of the compressors to be obtained. Average temperatures were 50 ^{o}C.

Acknowledgements

We wish to thank thank all partcipating BMR staff and the Master and crew of the R.V. Rig Seismic for their assistance in this program. We also wish to thank all of the oil exploration companies whose input greatly enhanced the value and relevance of the program. These companies included: WMC, BHP, Ampol, Norcen, Kufpec, Santos, Hadson, TCPL, BP, Marathon and Phillips.

SURVEY PERSONNEL

BMR
Cruise Leader:- G.W. O'Brien
Deputy Cruise Leader:- J.F. Marshall
Scientific Staff:- G. Bickford, J. Bishop & R. Whitworth
Systems Officers:-F. Brassil & E. Chudyk
Technical Staff:- J. Bedford, R. Curtis, B. Dickinson, S. Davey, P. Davies, C. Green, L. Hatch, T. McNamara, S. Milnes, J. Pittar, D. Pryce, A. Radley, D. Sewter, C. Tindall, J. Whatman & P. Vujovic,

D.O.T.
Master:- A. Codrington
Chief Officer:- W. McKay
Second Officer:- M. Gusterson

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List Of Tables

Table 1. Start and end of seismic lines, Survey 97, Timor Sea.

Line #	Start (GMT)	End (GMT)	Latitude (Start) (End)	Longitude (Start) (End)	Length (nm/km)	Bearing
97/025	304/0105	304/0401	12 58.2 12 56.5	124 37.4 124 50.8	13.11 24.29	39.5
97/026	304/0642	304/1706	12 56.5 12 35.7	124 50.4 124 21.9	34.97 64.8	309.4
97/027	304/1847	304/2104	12 37.1 12 27.5	124 23.5 124 17.3	11.38 21.10	329.3
97/028	304/2243	305/0507	12 29.8 12 11.5	124 19.7 123 52.6	32.11 59.51	300.3 294.3 309.7
97/029	305/0735	305/1919	12 06.0 12 37.5	124 02.4 124 35.7	45.26 83.87	125.3 132.8 127.7
97/030	305/2043	306/0143	12 36.4 12 45.6	124 33.7 124 57.8	25.18 46.66	111.2
97/031	306/0203	306/0943	12 46.0 12 26.4	124 59.3 124 27.7	36.55 67.72	302.0
97/032	306/1205	306/2015	12 28.9 12 15.9	124 30.7 124 20.3	16.45 30.48	322.0
97/033	306/2133	307/0258	12 18.3 12 02.1	124 22.8 124 00.06	27.07 50.15	303.3 308.7
97/034	307/0524	307/1121	11 57.6 12 16.5	124 10.6 124 34.8	30.35 56.25	125.9 123.1 138.5
97/035	307/1246	307/1413	12 13.8 12 19.5	124 32.5 124 36.3	6.92 12.82	147.1
97/036	307/1615	307/2328	12 16.8 12 41.6	124 34.2 125 02.3	36.89 68.36	134.4 129.2
97/037	308/0243	308/1747	12 38.3 11 51.5	125 05.5 124 15.0	68.04 126.08	312.3 314.8
97/038	308/2029	309/0122	11 49.1 12 08.5	124 22.4 124 38.5	24.90 46.14	141.0
97/039	309/0221	309/0508	12 08.1 12 05.1	124 36.3 124 50.4	14.14 26.21	78.6
97/040	309/0641	309/1320	12 03.5 12 30.9	124 46.6 125 04.7	32.55 60.31	149.3 144.9
97/041	309/1652	310/0209	12 23.7 11 54.1	125 12.2 124 57.6	32.89 60.95	332.6 337.4
97/042	310/0553	310/1222	11 59.708 11 32.734	125 00.608 124 41.633	32.75 60.69	326.7
97/043	310/1338	310/1729	11 34.855 11 22.159	124 43.511 124 28.881	19.15 35.48	311.6
97/044	310/2019	311/0726	11 31.742 12 03.457	124 26.772 124 55.483	39.91 73.95	138.2
97/045	311/0915	311/1537	12 00.579 12 17.246	124 51.912 125 20.067	51.36 95.18	119.5
97/046	311/1919	312/1242	12 18.052 11 14.048	125 16.932 124 37.445	74.7 138.5	332.2

Line #	Start (GMT)	End (GMT)	Latitude (Start) (End)	Longitude (Start) (End)	Length (nm/km)	Bearing
97/047	312/1554	313/0558	11 11.715 12 15.354	124 47.232 125 18.746	70.7 131.0	154.2
97/048	313/0852	313/1254	12 13.880 11 57.277	125 27.627 125 16.357	19.9 36.9	326.8
97/049	313/1436	313/1853	12 03.160 11 41.222	125 18.338 125 17.670	22.0 40.7	358.2
97/050	313/2138	314/0129	11 46.220 11 32.034	125 19.528 125 06.004	19.4 35.9	318.2
97/051	314/0348	314/1046	11 37.174 11 04.426	125 09.485 124 55.745	35.4 65.6	337.6
97/052	314/1141	314/1622	11 03.688 11 12.386	124 59.674 125 21.894	23.5 43.5	111.7
97/053	314/1827	314/2054	11 09.862 11 16.606	125 17.393 125 27.167	11.7 21.7	125.1
97/054	314/2241	315/0159	11 15.374 11 09.277	125 24.152 125 40.091	16.7 31.1	68.6
97/055	315/0353	315/0819	11 07.822 11 24.543	125 35.165 125 47.340	20.5 38.1	144.1
97/056	315/1000	315/1844	11 18.896 11 56.750	125 44.409 125 57.354	39.9 73.9	161.5
97/057	315/2103	316/0505	11 56.732 11 18.132	126 05.698 125 54.009	40.2 74.6	343.3
97/058	316/0645	316/1132	11 21.245 11 22.016	125 58.200 125 41.852	16.0 29.7	267.3
97/059	316/1400	316/2217	11 19.820 11 46.151	125 47.935 125 15.368	41.4 76.7	230.5
97/060	317/0041	317/0913	11 42.613 11 56.446	125 20.385 124 57.676	26.1 48.5	238.1
97/061	317/1129	317/1827	11 52.719 12 16.400	125 02.787 124 36.270	35.1 65.0	227.6
97/062	317/2042	318/0741	12 11.977 12 39.069	124 40.604 124 17.421	35.3 65.4	219.9
97/063	318/0602	318/1304	12 32.617 13 02.856	124 16.902 124 35.997	35.5 65.8	148.4
97/064	318/1435	319/0358	13 02.308 12 10.374	124 30.487 125 15.657	68.1 126.2	40.3
97/065	319/0615	319/1218	12 13.812 12 06.744	125 10.373 125 41.219	30.9 57.4	76.8
97/066	319/1418	320/0756	12 10.722 11 05.599	125 38.339 125 25.043	66.4 123.3	348.7
97/067	320/0836	320/2348	11 07.228 11 41.277	125 23.042 125 58.667	48.7 90.4	215.1
97/068	321/0228	321/1030	11 36.810 12 00.834	125 03.131 124 27.294	42.5 78.8	233.6

Table 1 continued.

Table 2. Direct hydrocarbon detection lines, Survey 97, Timor Sea.

Line #	Lat. Start Lat. Finish	Long. Start Long. Finish	J.Day Start J.Day Finish	GMT Start GMT Finish	Line Length (nM/km)
97/025	12 57.74	124 37.84	304	0111	12.5
	12 48.28	124 45.82	304	0337	23.16
97/026	12 55.455	124 49.392	304	07 02	46
	12 36.070	124 22.799	304	16 52	85.24
97/027	12 35.932	124 22.836	304	19 01	8
	12 29.159	124 18.614	304	20 41	14.8
97/028	12 29.683	124 19.482	304	22 43	30.6
	12 12.006	123 53.128	305	04 59	56.7
97/029	12 05.538	124 02.130	305	07 26	49.65
	12 37.514	124 35.731	305	19 17	92.00
97/030	12 36.449	124 33.887	305	20 45	25.2
	12 45.601	124 57.826	306	01 42	46.7
97/031	12 45.700	124 58.970	306	02 31	34.7
	12 27.563	124 29.594	306	09 14	64.3
97/032	12 30.639	124 30.807	306	11 58	14.8
	12 15.931	124 20.384	306	20 14	27.4
97/033	12 15.090	124 20.699	306	21 38	22.8
	12 02.598	124 01.085	307	02 50	42.2
97/034	11 59.979	124 13.891	307	06 10	26.1
	12 16.357	124 34.648	307	11 18	48.4
97/035	12 13.862	124 32.577	307	12 44	7.5
	12 19.496	124 36.293	307	14 05	13.9
97/036	12 17.112	124 34.545	307	16 16	36.75
	12 45.018	125 06.740	308	00 31	68.10
97/037	12 37.718	125 04.769	308	02 49	71.3
	11 51.472	124 14.967	308	17 45	132.1
97/038	11 50.303	124 23.349	308	20 43	25.9
	12 08.485	124 38.441	309	01 21	48.0
97/039	12 07.761	124 36.95	309	0225	13.7
	12 05.005	124 50.614	309	0504	25.4
97/040	12 04.350	124 47.121	309	0650	31.9
	12 30.545	125 04.458	309	1309	59.1
97/041	12 22.954	125 11.797	309	1700	31.8
	11 54.05	124 57.54	310	0356	58.9
97/042	11 58.892	125 00.05	310	0554	32.1
	11 32.807	124 41.661	310	1215	59.5
97/043	11 32.66	124 41.613	310	1341	16.5
	11 34.549	124 43.12	310	1701	30.6
97/044	11 32.023	124 26.971	310	2258	42.4
	12 03.285	124 55.332	311	0725	78.6
97/045	12 00.842	124 52.384	311	0919	37.2
	12 17.207	125 20.001	311	1534	68.9
97/046	12 17.816	125 16.758	311	2152	72.1
	11 14.421	124 37.641	312	1235	133.6
97/047	11 11.601	124 47.163	312	1550	73.5
	12 15.318	125 18.727	313	0555	136.2

Line #	Lat. Start Lat. Finish	Long. Start Long. Finish	J.Day Start J.Day Finish	GMT Start GMT Finish	Line Length (nM/km)
97/048	12 10.952 11 57.473	125 25.635 125 16.482	313 313	0930 1249	18.7 34.7
97/049	12 02.916 11 41.062	125 18.349 125 17.668	313 313	1437 1851	21.8 40.4
97/050	11 46.331 11 33.288	125 19.691 125 07.267	313 314	2146 0108	19.8 36.7
97/051	11 36.917 11 04.772	125 09.375 124 55.866	314 314	0349 1041	34.7 64.3
97/052	11 03.326 11 12.397	124 58.752 125 21.92	314 314	1127 1619	21.3 39.5
97/053	11 09.98 11 17.043	125 17.572 125 27.813	314 314	1827 2051	11.3 20.9
97/054	11 15.296 11 09.31	125 24.645 125 40.00	314 315	2243 0156	13.8 25.6
97/055	11 08.186 11 24.246	125 35.435 125 47.135	315 315	0356 0810	20.3 37.6
97/056	11 19.047 11 56.773	125 44.465 125 57.362	315 315	1000 1841	39.8 73.8
97/057	11 56.500 11 18.527	126 05.69 125 54.115	315 316	2104 0500	36.8 68.2
97/058	11 21.276 11 21.987	125 57.421 125 42.478	316 316	0648 1126	16.1 29.8
97/059	11 20.236 11 46.247	125 47.413 125 15.253	316 316	1405 2215	41.0 76.0
97/060	11 42.698 11 56.084	125 20.244 124 58.249	317 317	0041 0905	31.7 58.8
97/061	11 52.946 12 16.419	125 02.545 124 36.246	317 317	11 31 1823	35.4 65.6
97/062	12 12.216 12 38.807	124 40.414 124 17.638	318 318	2043 0337	34.8 64.5
97/063	12 33.060 13 02.788	124 17.182 124 35.951	318 318	0606 1300	35.8 66.4
97/064	13 02.109 12 10.885	124 30.656 125 15.212	318 319	1436 0350	66.7 123.7
97/065	12 13.788 12 06.834	125 10.472 125 40.731	319 319	0614 1212	30.7 56.9
97/066	12 09.750 11 06.623	125 38.143 125 25.240	319 320	1428 0744	65.0 120.5
97/067	11 08.590 11 39.024	125 22.067 125 00.29	320 320	0853 2346	40.5 75.1
97/068	11 36.921 12 00.982	125 02.955 124 27.063	321 321	0230 1034	42.5 78.8

Table 2 continued.

Table 3. Water column geochemical anomalies detected during Survey 97.

Anomaly Number	Line Number	Location/ Association
1	97/25	Transfer fault on edge of Vulcan Sub-Basin south-east of Montara 1
2	97/28	Ashmore Platform near Cartier 1 well
3	97/29	Skua Trend
4	97/31	Skua Trend
5	97/32	Skua Trend
6	97/36	Near East Swan well
7	97/37	Ashmore Platform north-west of Swan 1 (very weak)
8	97/62	Skua Trend
9	97/63	Transfer fault/aeromagnetic high on edge of Vulcan Sub-Basin
10	97/64	Transfer fault on the edge of the Vulcan Sub-Basin

List Of Figures

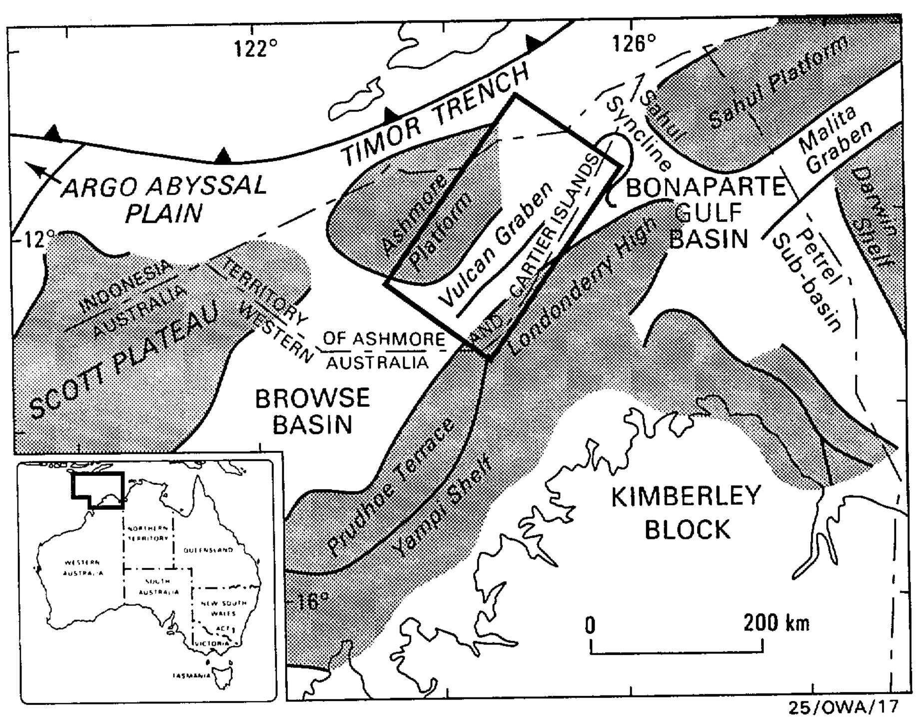

Figure 1. The major structural elements of the Timor Sea region. The shaded area shows the general location of the survey area. Map is redrawn from Patillo & Nicholls (1990).

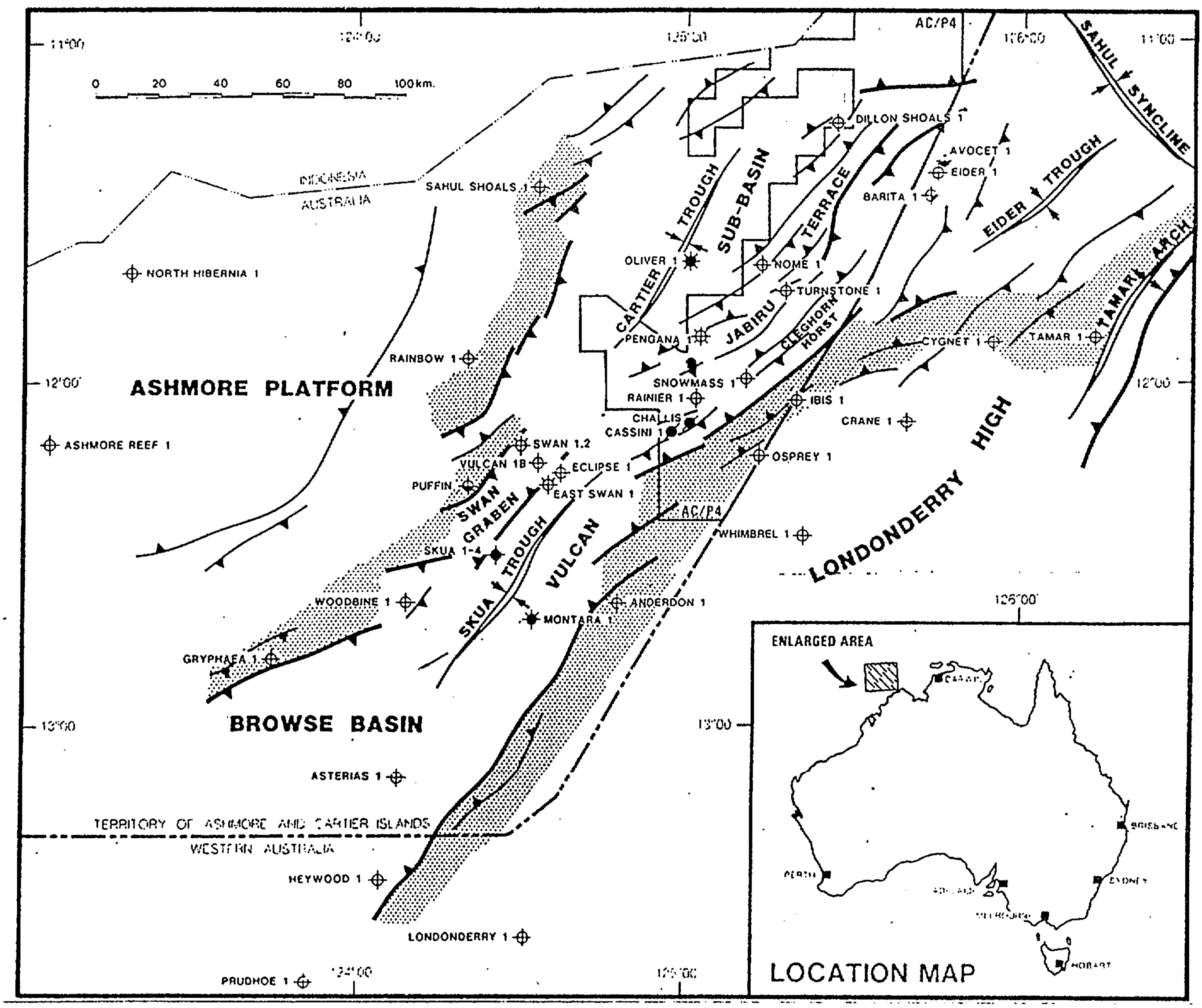

Figure 2. Structural elements of the Vulcan Sub-Basin (after Patillo & Nicholls, 1990).

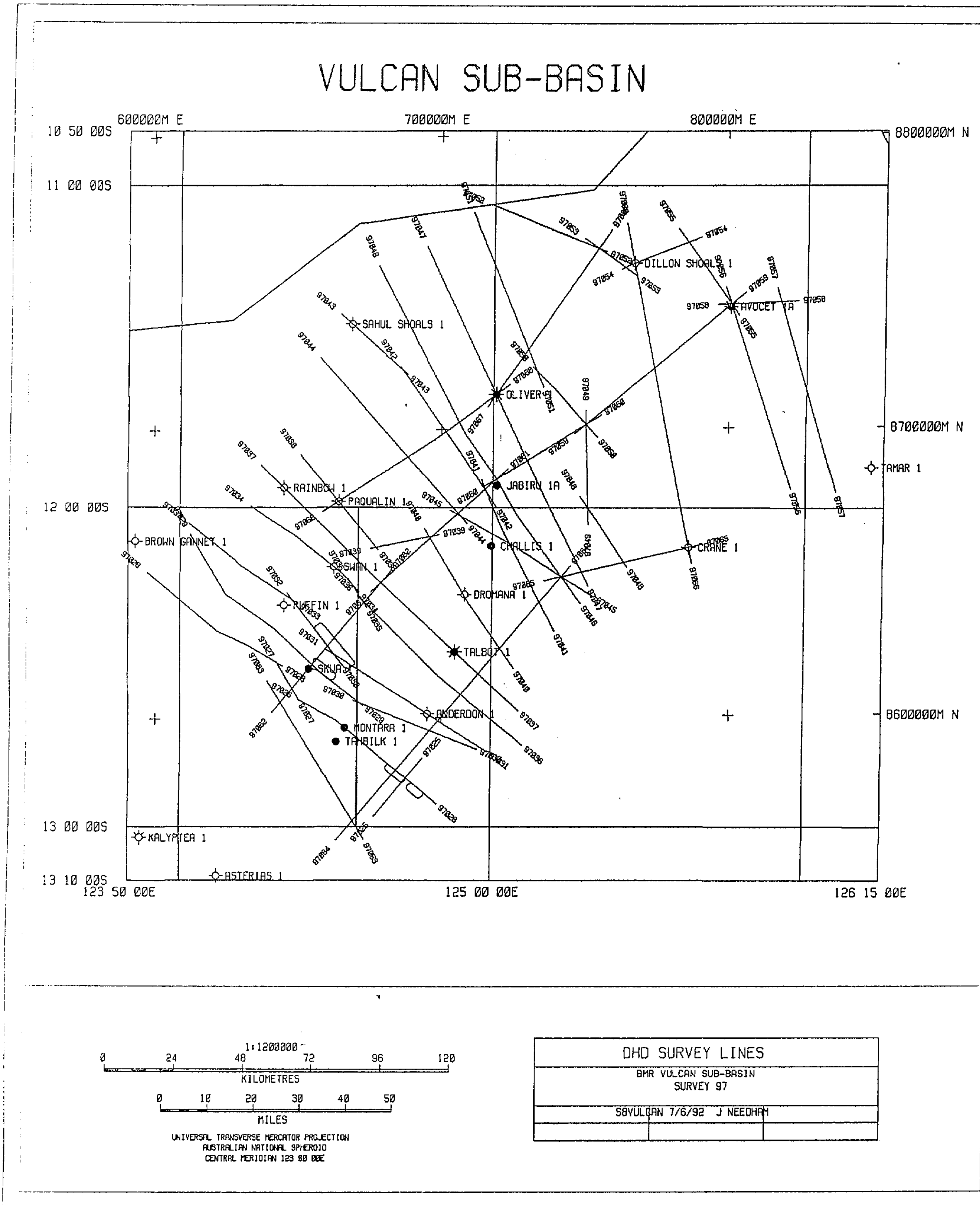

Figure 3. Track map showing the positions of the seismic/DHD lines acquired during Survey 97 within the Vulcan Sub-Basin, Timor Sea.

Appendix 1

General details: R.V. *Rig Seismic*

Rig Seismic is a seismic research vessel with dynamic positioning capability, chartered and equipped by BMR to carry out the Continental Margins Program. The 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

Geopysical 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

Trimble Differential GPS System (Dampier Sub-Basin)
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
Arma Brown and Robertson gyro-compasses; plus Ben paddle log
Decca HIFIX-6 radio-navigation system, modified for long range operations

Seismic system

Seismic cable

Fjord Instruments, transformerless analogue
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
288 seismic channels, 12 auxiliary channels
Maximum towable length 6000 metres
3600 metres available at present (Sept 1990)

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

Recording Parameters

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

Seismic System Configuration For High Resolution Seismic: Vulcan Sub-Basin

The recording parameters used during the high resolution seismic survey in the Vulcan Sub-Basin were 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 5 metres.

Streamer

Fjord Instruments transformerless.
10 Teledyne T-l hydrophones per 6.25m group.
900 m cable, 144 seismic channels,
group interval 6.25 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
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.

Appendix 3

Data Formats

SEGY-Y MAGNETIC TAPE HEADERS

The BMR field tapes are written in a modified SEG-Y format.

The records are written in 16-bit fixed point format (sample code 3) as defined in the report: *Recommended Standards for Digtital Tape Formats, Geophysics, vol 40, No 2 (April 1975) pp 344-352.*

The first 3200 bytes on the tape are the ASCII reel identification header.

The next 400 bytes are the binary coded block part of the reel identifaction header.

The 240 byte trace headers are in 16-bit fixed point format and is standard for the non-optional words.

The trace data is in BMR's Instantaneous Floating Point format (IFP). The format of these data is given in this appendix

SEGY-Y MAGNETIC TAPE HEADERS

A.1 DEFINITION OF TAPE HEADERS

Binary reel header for SEG-Y format magnetic tapes

WORD	DESCRIPTION	FORMAT
1-2	SURVEY NUMBER	I-32
3-4	LINE NUMBER (only one line per tape)	I-32
5-6	TAPE NUMBER	I-32
7	NUMBER OF SEISMIC TRACES PER SHOT	I-16
8	NUMBER OF AUXILIARY CHANNELS	I-16
9	SAMPLE INTERVAL (microsecs) (for this tape)	I-16
10	SAMPLE INTERVAL (microsecs) (for original recording)	I-16
11	NUMBER SAMPLES PER DATA TRACE (for this tape)	I-16
12	NUMBER SAMPLES PER DATA TRACE (for original recording)	I-16
13	DATA FORMAT CODE 1. floating point (4 bytes) 3. fixed point (2 bytes) ?. floating point (2 bytes)	I-16
14	CDP FOLD	I-16
15	TRACE SORTING 1. as recorded (preset to this)	I-16
16	VERTICAL SUM CODE 1. no sum (preset to this)	I-16
17-26	unassigned	
27	AMPLITUDE RECOVERY METHOD 1. none (preset to this)	I-16
28	MEASUREMENT SYSTEM 1. metres	I-16
29-200	unassigned	

SEGY-Y MAGNETIC TAPE HEADERS

Standard portions of SEG-Y format used by Marine Division

WORD	DESCRIPTION	FORMAT
1-2	TRACE SEQUENCE NO. WITHIN LINE	I-32
3-4	TRACE SEQUENCE NO. ON TAPE	I-32
5-6	FIELD SHOT POINT NUMBER	I-32
7-8	CHANNEL NUMBER WITHIN SHOT	I-32
9-14	unassigned	
15	TRACE IDENTIFICATION CODE	I-16
	*1 - seismic data	
	*2 - dead	
	*3 - dummy	
	4 - time break	
	5 - uphole (land only)	
	6 - sweep	
	7 - timing	
	*8 - water break	
	*9 - oscillator test	
	*10 - noise test	
	*11 - cable/oscillator test	
	*12 - airgun signature	
	*13 - airgun shuttle sensor	
	*14 - sonobouy	
	Note: * indicates implemented in this system	
16	NO. OF VERTICALLY STACKED TRACES (preset to 1)	I-16
17	NO. OF HORIZONTALLY STACKED TRACES (preset to 1)	I-16
18	DATA USE 1. production (preset to this) 2. test data	I-16
19-20	DISTANCE FROM SOURCE TO RECEIVER (negative value as opposite to travel direction)	I-32
21-22	GROUP DEPTH (negative as below sea level)	I-32
23-24	SURFACE ELEVATION AT SOURCE (preset to 1)	I-32
25-26	SOURCE DEPTH (negative as below sea level)	I-32
27-28	DATUM ELEVATION AT RECEIVER GROUP	I-32
29-30	DATUM ELEVATIONAT SOURCE	I-32
31-32	WATER DEPTH AT SOURCE	I-32
33-34	WATER DEPTH AT GROUP	I-32
35	DEPTH SCALAR (preset to -10)	I-16
36	CO-ORDINATE SCALER (preset to 1)	I-16
37-54	unassigned	
46	AUX. GAIN (set temporarily)	I-16
55	RECORDING DELAY IN (millisecs)	I-16
56-57	unassigned	
58	NUMBER OF SAMPLES IN RECORD	I-16
59	SAMPLE INTERVAL (microsecs)	I-16
60	GAIN TYPE OF FIELD INSTR. 1. fixed gain (preset to this) 3. floating point gain	I-16

61	SEISMIC AMPLIFIER GAIN	I-16
62-74	unassigned	
75	LOW-CUT FILTER FREQUENCY	I-16
76	HIGH-CUT FILTER FREQUENCY	I-16
77	LOW-CUT FILTER SLOPE db/octave (preset at 18 dB/octave)	I-16
78	HIGH-CUT FILTER SLOPE db/octave (preset at 72 dB/octave)	I-16
79	SHOT INSTANT -year data recorded	I-16
80	SHOT INSTANT -day of year	I-16
81	SHOT INSTANT -hour of day	I-16
82	SHOT INSTANT -minute of hour	I-16
83	SHOT INSTANT -second of minute	I-16
84	TIME BASE CODE 1. local 2. GMT (preset to this) 3. other	I-16
85-90	unassigned	

Usable words in SEG-Y trace header - July 1991

WORD	DESCRIPTION	FORMAT
37	NUMBER OF SOURCE GUNS	I-16
38	GUN TRIGGER DELAYS FOR "CHANNEL" GUN IN 10ths OF MILLISECS	I-16
39	NUMBER OF SOURCE GUNS	I-16
40	GUN FIRING ERROR FOR "CHANNEL" GUN IN 10ths OF MILLISECS	I-16
41	NUMBER OF CABLE BIRD DEPTH SENSORS	I-16
42	DEPTH OF "CHANNEL" BIRD IN 10ths OF METRES	I-16
43	NUMBER OF CABLE BIRD WING ANGLES	I-16
41	ANGLE OF "CHANNEL" BIRD WING IN 10ths OF DEGREES	I-16
91	SHOT INSTANT - fraction of sec (msecs)	I-16
92	INTERVAL FROM LAST SHOT (msecs)	I-16

A.2 INSTANTEOUS FLOATING POINT FORMAT

The trace data is in 16-bit floating point format as follows:

```
 1   1   1   1   1   1
 5   4   3   2   1   0   9   8   7   6   5   4   3   2   1   0
---------------------------------------------------------------
| s|  exponent       |              mantissa                  |
---------------------------------------------------------------
```

The data is in 2's complement format with bits 0-10 the mantissa, bits 11-14 the exponent and bit 15 the sign.

The mantissa normally varies between 1024 and 2047 except when the exponent is zero.

The exponent can vary from 0 to plus or minus 9 only, a number is illegal if it has an exponent with an absolute value greater than 9.

The converted integer ranges of the floating point number for each exponent range and the equivalent voltage ranges (for positive values) are:

Exponent	Integer Range	Voltage Range
0	0 - 2047	0.0 - 0.01953125
1	2048 - 4097	0.01953125 - 0.0390625
2	4098 - 8193	0.0390625 - 0.078125
3	8192 - 16383	0.078125 - 0.15625
4	16383 - 32767	0.15625 - 0.3125
5	32768 - 65535	0.3125 - 0.625
6	65536 - 131071	0.625 - 1.25
7	131072 - 262143	1.25 - 2.5
8	262144 - 524287	2.5 - 5.0
9	524288 - 1048575	5.0 - 10.0

There are a total of 11264 IFP numbers possible for both positive and negative numbers.