Bureau of Mineral Resources, Geology & Geophysics

RECORD

BUREAU OF MINERAL RESOURCES

RECORD 1990/68

RESEARCH CRUISE PROPOSAL

VULCAN GRABEN, TIMOR SEA: DEEP CRUSTAL STRUCTURE, STRUCTURAL REACTIVATION, AEROMAGNETICS AND HYDROCARBON MIGRATION

PROJECT 121.19

PRINCIPAL INVESTIGATORS:- G.W. O'BRIEN & P.E. WILLIAMSON

SCHEDULE:- OCTOBER-DECEMBER 1990

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EXECUTIVE SUMMARY

Objective:-To understand the deep crustal architecture, the structural reactivation processes and the mechanisms of hydrocarbon generation, migration and entrapment within the Vulcan Graben, Timor Sea.

The discovery of hydrocarbons in the Jabiru, Challis, Skua, Oliver, Talbot and Montara exploration wells has substantially upgraded the prospectivity of the Timor Sea (Figure 1). In order to further stimulate and assist the exploration effort in this area, the Division of Marine Geosciences and Petroleum Geology (Bureau of Mineral Resources) is, as part of its Continental Margins Program, carrying out a series of research projects within the Timor Sea. These projects will assist in the assessment of the area's prospectivity by integrating high resolution seismic reflection, deep crustal seismic reflection, aeromagnetic, and remote sensing (direct hydrocarbon detection (DHD)) geochemical data. This will result in an improved understanding of:-

1.)The timing of structural development relative to hydrocarbon generation and migration. This will be addressed by integrating high resolution seismic data, DHD geochemical data and geohistory and maturation modelling data.

2.)The relationship between structural reactivation and hydrocarbon migration and trapping mechanisms. This will be addressed principally by integrating high resolution seismic, side scan sonar and DHD geochemical data, supported by deep crustal seismic information.

3.)The basin architecture and the history of basin formation. This will be addressed principally by integrating deep crustal seismic and aeromagnetic data.

The data acquisition and interpretation parts of the Vulcan Graben Project can be sub-divided into three sub-projects. The acquisition phases will be carried out during two "RIG SEISMIC" surveys in October-

November and November-December 1990 (see Figures 2 & 3). These sub-projects will be integrated with Project 221.04, which comprises a regional aeromagnetic study of the Vulcan Graben region. The objectives of these sub-projects are:-

i.)High Resolution Seismic Reflection Data To acquire approximately 2500 line km of high resolution seismic reflection data with a 3 second record length (Figure 2). The data collection phase will be between mid-October and mid-November 1990, and the data will be used to study in detail the processes of structural reactivation associated with collision and foreland basin development along the northern margin of the Australian craton. Ancillary objectives include detailed studies of the geometries of possible transfer/accommodation faults, as delineated on high resolution aeromagnetic data. Side-scan sonar data will be acquired in conjunction with the high resolution seismic data so that the seafloor expression and orientation of reactivated faults can be mapped.

ii.)Remote Sensing Geochemical Data To acquire approximately 2500 line km of direct hydrocarbon detection (C_1-C_8^+) data (DHD) in the water column within the Vulcan Graben and surrounding areas (Figure 2). The data collection phase will be between mid-October to mid-November 1990. This data will be collected over structures which cover the range of hydrocarbon-bearing and non-productive structural styles within the graben. Data will also be collected over a number of as yet undrilled prospects. The DHD data will be collected simultaneously with the high resolution seismic and side-scan sonar data, allowing geochemical anomalies to be related to both seafloor and sub-seafloor geology. In addition, sediment cores will be taken in conjunction with the DHD program, and the molecular and isotopic compositions of the light hydrocarbon gases composition of the pore waters within the sediments will be determined. 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.

iii.)Deep Crustal Seismic Data To acquire approximately 3000 line km of deep crustal (15 second record length) seismic reflection data (Figure 3). The data collection phase will be mid-November to mid-December 1990. The survey is positioned so that, for the first time, the overall basin architecture and its linkage with adjacent structural elements can be characterized.

LIST OF FIGURES

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1. INTRODUCTION

1.1 STUDY AREA, REGIONAL GEOLOGY AND TECTONIC EVOLUTION

The Vulcan Graben 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 Graben itself is sub-divided into a series of NE- and ENE-trending sub-grabens (Figures 2 & 3) which are separated by intra-graben terraces (Patillo and Nicholls, 1990).

The tectono-stratigraphic evolution of the Vulcan Graben, 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 Graben 'proper', is comprised of late Callovian to early Valanginian siliciclastics. Intense faulting during this time introduced a strong E-NE orientation to the graben. 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 Graben 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 sediments ranging in age from late Valanginian to Quaternary. This sequence reflects the thermal subsidence phase with the development of a passive continental margin, with the sequence becoming progressively more marine with time. During the Late Miocene, the northward-moving Australasian 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 Graben, 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).

2. OBJECTIVES

2.1 SURVEY I:-STRUCTURAL REACTIVATION AND HYDROCARBON MIGRATION

Survey I has several objectives, which fall into four broad, often inter-related categories. By acquiring high resolution seismic reflection data, direct hydrocarbon detection data (DHD), gravity and magnetic data, and side-scan sonar data simultaneously, it is hoped that most of these objectives can be achieved concurrently. The objectives are:-

i.)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). Side-scan sonar data, which will be acquired in conjunction with the high resolution seismic data, should allow the seafloor expression and orientation of reactivated faults can be mapped.

ii.)To obtain closely spaced high resolution seismic reflection data over parts of the Vulcan Graben in order to better understand the factors controlling the short wavelength magnetic anomalies which have been previously defined by the aeromagnetic survey conducted for Project 221.04. 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, 1990). 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.

iii.)The Direct Hydrocarbon Detection method (DHD) has not been extensively used in Australia, and the majority of surveys that have been conducted are not in the publically available. A small 'sniffer' survey conducted by InterOcean in the Timor Sea for BHP in 1989 falls into this category. The Timor Sea would appear 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 will be acquired in conjunction with high resolution seismic and side-scan sonar data over a complete range of structural styles within the basin. Detailed surveys will be carried out over the following hydrocarbon discoveries:- Skua, Montara, Puffin, Oliver, Talbot, Keeling, Pengana. This will allow the method to be 'ground-truthed', and the composition of any detected hydrocarbon anomalies to be compared with that found in the reservoir. Surveys will also be carried out over a large number of (as yet) undrilled prospects throughout the Vulcan Graben. This will allow the usefulness of the method as a predictive tool to be assessed. Other specific DHD investigations include:- detailed work in the vicinity of the Avocet 1A structure, which was an oil field breached during the Late Tertiary fault 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.

The DHD data will be collected simultaneously with the high resolution seismic and side-scan sonar data, allowing geochemical anomalies to be related to both seafloor (eg. pockmarks) and sub-seafloor geology. In addition, sediment cores will be taken in conjunction with the DHD program, and the molecular and isotopic compositions of the light hydrocarbon gases composition of the pore waters within the sediments will be determined. 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.

iv.)No detailed sedimentological studies have been carried out in the Timor Sea for many years. Consequently, it is hoped to characterise the marine geology of the area during the survey. Vibrocores and gravity cores will be taken (in conjunction with the sediment geochemical program) along selected DHD/high resolution seismic lines. It is hoped that the integration of sedimentological data with image processed digital side-scan sonar data will allow predictive facies models to be developed.

The areas to be studied during Survey I are shown in Figure 2.

2.2 SURVEY II:-DEEP CRUSTAL STRUCTURE AND BASIN ARCHITECTURE

The deep crustal study has the objective of defining the three dimensional basinal architecture of the Vulcan Graben and associated features, in sufficient detail to be an aid to understanding the structural controls on basin development, sedimentation, trap formation and the migration of hydrocarbons. This contrasts with deep-crustal seismic studies world-wide, which are characteristically dominantly two-dimensional in nature.

The data will also be collected with the secondary objective of providing regional stratigraphic ties between exploration wells. The study will utilise an approximate 3000 km grid (Figure 3) of seismic reflection data designed to image the crust and upper mantle. 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.

The margins of the Vulcan Graben are associated with major normal fault systems which almost certainly affect the lower crust. Structures from the formation of the basin to Mesozoic time show multiple periods of rifting and extension relating to the formation of the Paleozoic rift and the Mesozoic continental margin. The interaction between the major Tertiary compressional pulse associated with the collision between the Australian continent and Timor, and the prior architecture of the Vulcan Graben, was probably instrumental in providing additional Mesozoic trapping structures and, most importantly, migration paths for hydrocarbons. The deep-crustal data set may thus provide a predictive tool in the search for further petroleum accumulations.

3. REFERENCES

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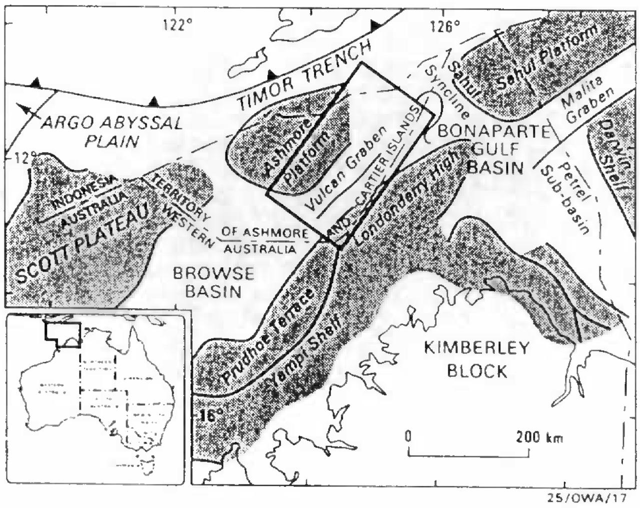

Figure 1. Major structural elements of the Timor Sea region (after Pattillo and Nicholls, 1990).

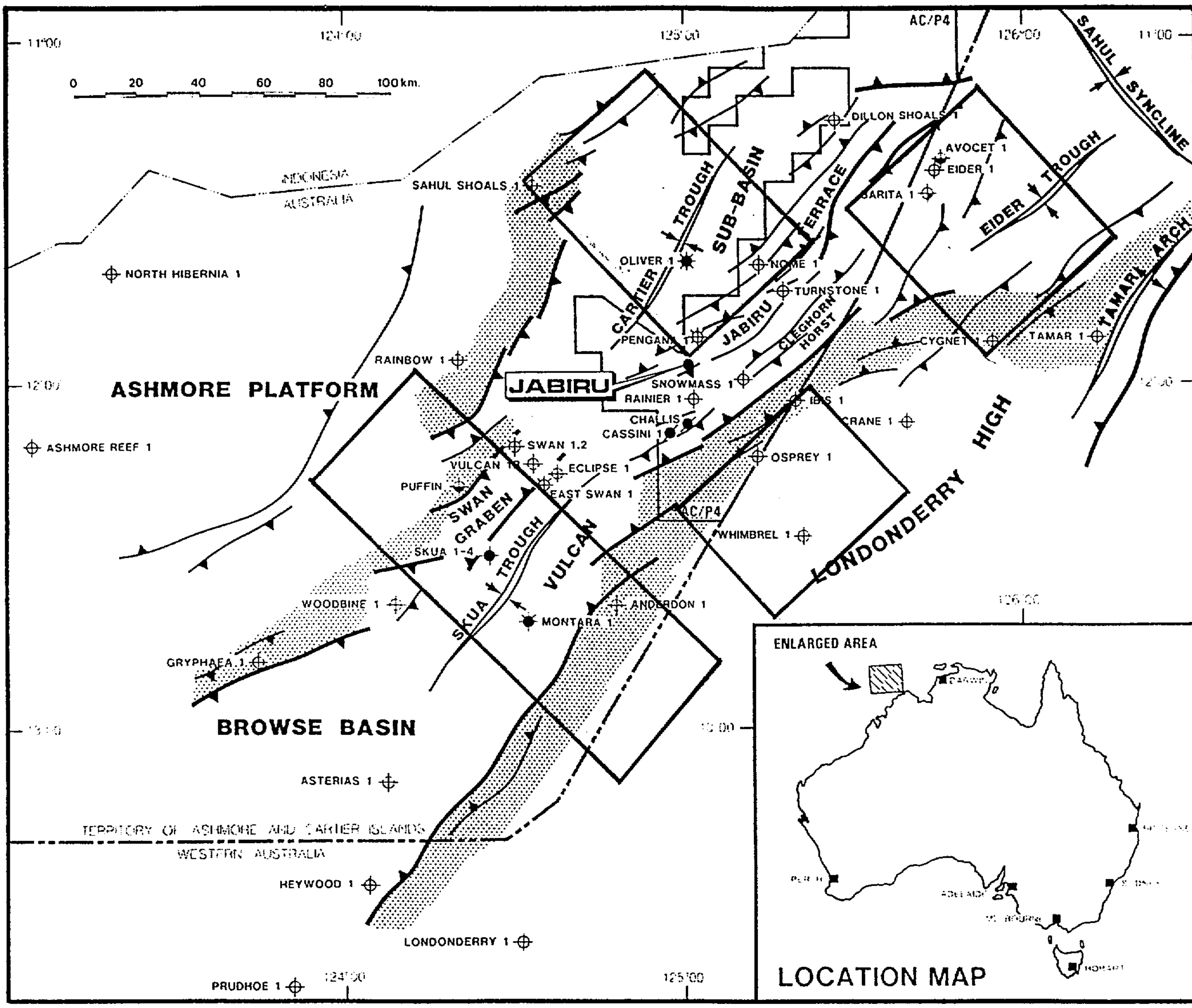

Figure 2. Structural elements of the Vulcan Graben showing the location of the planned high resolution seismic/DHD 'Rig Seismic' program (Survey I). Map after MacDaniel (1988).

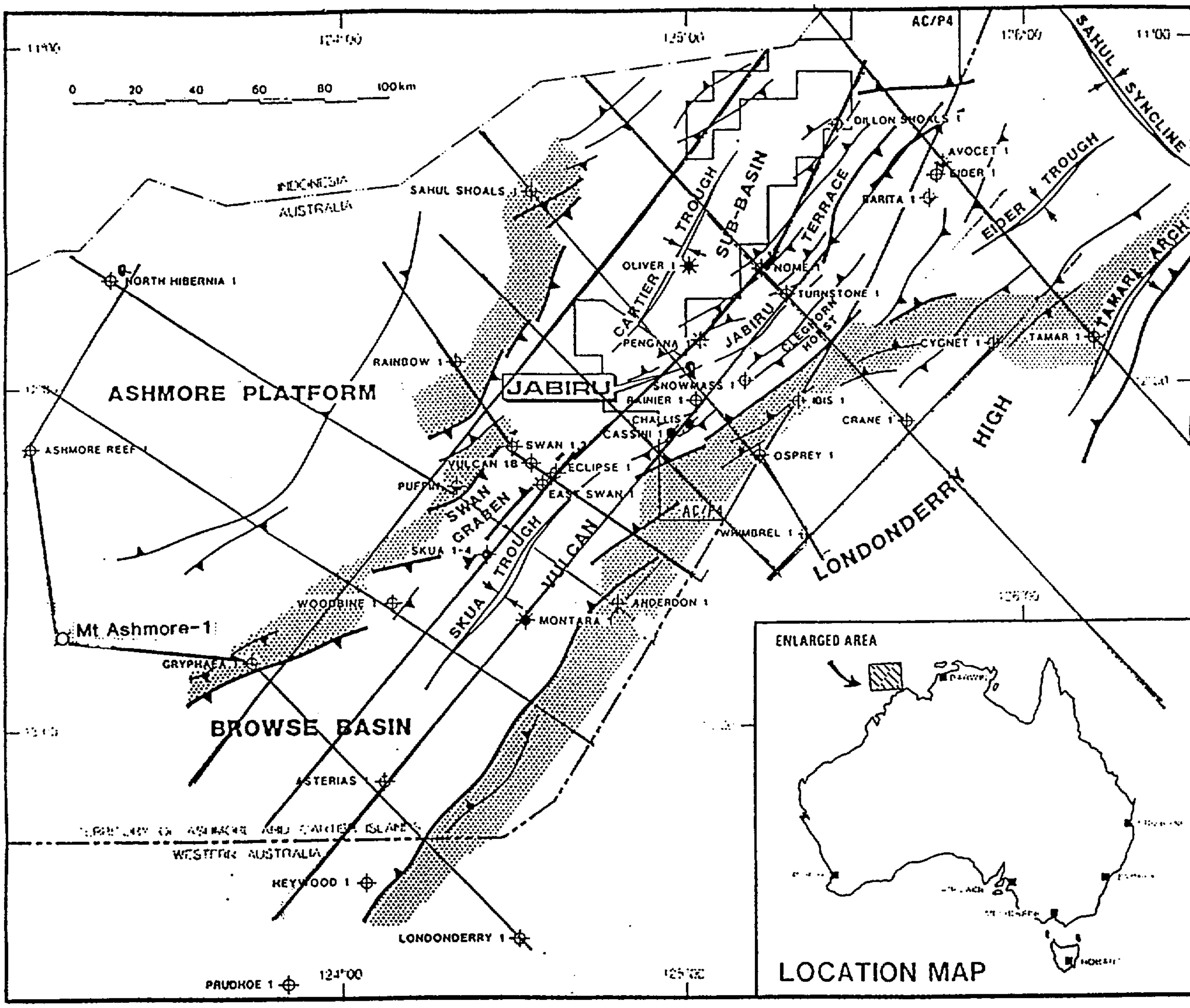

Figure 3. Structural elements of the Vulcan Graben showing the location of the planned 'Rig Seismic' deep crustal seismic survey (Survey II). Map after MacDaniel (1988).

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
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 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
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

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

SEISMIC SYSTEM CONFIGURATION FOR HIGH RESOLUTION PROGRAM:- SURVEY I

The anticipated recording parameters to be used on the experimental high resolution seismic survey in the Vulcan Graben and surrounds are 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 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 routinessupplied.

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.

SEISMIC SYSTEM CONFIGURATION FOR DEEP CRUSTAL PROGRAM:- SURVEY II

The anticipated recording parameters to be used on the deep crustal seismic program in the Vulcan Graben and surrounds are as follows.

SEISMIC SYSTEM

Streamer
Fjord Instruments transformerless.
3750 m cable, 100 seismic channels,
group interval 37.5 m.
depth 10m nominal.

Field Data
8 hz - 256 hz passband
2/4 ms demultiplexed
up to 15 sec record length
nominal 18.5 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

GEOLOGICAL SCIENTIFIC EQUIPMENT

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

GEOCHEMICAL SCIENTIFIC EQUIPMENT

Sediment And Porewater Geochemistry
Flow injection analyser
UV-VIS spectophotometer
Gas chromatographs

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

EXPECTED OUTCOMES/ PRODUCTS FROM PROJECT 121.19

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

Regional magnetic anomaly maps.

Regional deep crustal seismic sections showing the main structural elements of the Vulcan Graben and their relationship to the surrounding structural elements. Revised regional tectonic elements maps and structural sections.

High resolution seismic data with particular emphasis on the resolution of structural features at the Valanginian Unconformity level and shallower. Maps over selected structural features.

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

Regional maps of the distribution of light hydrocarbons in the water column and in the surficial sediments, and 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.

APPENDIX 4

COMPANY INTERESTS:- VULCAN GRABEN

NORTHERN TERRITORY

EXPLORATION LICENCES

PERMIT	TITLE HOLDER	EXPIRY DATE
AC/P 1	HARTOGEN	O4-06-91
	SANTOS	
	AGL	
AC/P 2B	BHP PETROLEUM*	30-11-90
BALANCE	SANTOS	
	COMMAND	
	MINORA	
	NORCEN	
	HOME	
	PEKO	
	AMPOL	
	WEEKS	
AC/P 2P	BHP*	
PUFFIN	COMMAND	
	AMPOL	
	SANTOS	
	MINORA	
	PEKO	
	NORCEN	
	WEEKS	
AC/P 2S	BHP*	

SWAN	SANTOS	
	PEKO	
	AMPOL	
	COMMAND	
	NORCEN	
	MINORA	
	WEEKS	
AC/P 3	BHP PETROLEUM	13-11-91
	PACIFIC OIL (CRA)	
	INPEX LTD	
	SANTOS	
AC/P 4	BHP PETROLEUM*	18-03-91
	EXXON	
	BRENDA	
	NORCEN	
	NORPAC	
	PEKO	
	AMPOL	
AC/P 5	BP*	03-04-92
	NATIONAL MUTUAL	
	BARCOO PET LTD	
	SANTOS	
AC/P 6	BHP PETROLEUM*	03-04-92
	AMPOL	
	BRENDA	
	NORPAC	
	PEKO	
	SANTOS	
AC/P 7	BHP PETROLEUM*	03-04-92
	CONOCO	
	INPEX	
AC/P 9	HADSON	24-08-92

	SANTOS*	
	BHP	
	PETROCORP	
	COMADA	
AC/P 10	SANTOS	27-02-95
	BEACH	
	NORCEN*	
	TOTAL	
AC/P 11	WESTERN MINING*	27-02-95
	TRAFALGAR	
	SANTOS	
	YUKONG	
	AMPOL	
AC/P 12	SANTOS*	27-02-95
	IDEMITSU	
	TOTAL	
	BEACH	
	NORCEN	
AC/P 13	TCPL*	27-02-95
	BRIDGE	
	HADSON	
	MINORA	
	GAS & FUEL	
	WESTERN MINING CORPORATION	
	HARDIE PET	
	CNW OIL (AUST)	

PRODUCTION LICENCES

AC/L 1-2	BHP PETROLEUM*	16-07-06
JABIRU	ESSO	
	AMPOL	

	BRENDA	
	NORPAC	
	NORCEN	
	SANTOS	
AC/L 3	BHP PETROLEUM*	28/01/09
CHALLIS	ESSO	
	AMPOL	
	BRENDA	
	NORPAC	
	NORCEN	
	SANTOS	

WESTERN AUSTRALIA

EXPLORATION LICENCES

WA-147-P	WESTERN MINING*
	BRIDGE
	AMPOL
	MINORA
	PEKO
	COMMAND
	TEXAS INTER
	ESSO
	PELSOIL
WA-199-P	NORCEN*
	AGL
	BRIDGE
	BOND

*** Denotes Operator**

APPENDIX 5

WELLS DRILLED IN THE TIMOR SEA

WELL NAME	LATITUDE (oS)	LONGITUDE (oE)	WATER DEPTH (m)
Allaru 1	12.093406	124.798173	-125
Allaru 1	12.093406	124.798173	-125
Allaru 1	12.093406	124.798173	-125
Anderdon 1	12.646416	124.796593	-97
Anson 1	12.502971	124.8035	-99
Arunta 1	11.975496	124.951508	-122
Ashmore Reef 1	12.180472	123.086277	-39
Asterias 1	13.152305	124.119998	-194
Avocet 1	11.373053	125.755	-105
Avocet 1A	11.372813	125.755068	-105
Avocet 2	11.364093	125.757075	-106
Barita 1	11.443318	125.728188	-94
Bassett 1	13.31111	123.42667	-372
Bassett 1A	13.311583	123.425222	-372
Bilyara 1	12.684654	124.505886	-82
Bilyara 1 ST1	12.684654	124.505886	-82
Birch 1	12.460841	124.495348	-87
Brewster 1	13.91361	123.2589	-256
Brewster 1A	13.913706	123.259511	-256
Brown Gannet 1	12.108056	123.856111	-110
Browse Island 1	14.112555	123.549193	2.9
Buccaneer 1	13.616666	124.016666	-149
Cartier 1	12.244166	123.940276	-100
Cassini 1	12.146501	124.968138	-116
Cassini 1	12.146498	124.968136	-116
Cassini 2	12.148551	124.949416	-113
Casuarina 1	12.052446	125.098658	-95
Challis 1	12.123753	125.00446	-108.2
Challis 2	12.121666	125.018333	-98
Challis 2A	12.121286	125.018568	-105
Challis 3	12.115125	125.022888	-102
Challis 4	12.129268	124.995086	-108
Challis 5	12.122263	124.996666	-107.3
Challis 6	12.109661	125.034593	-99
Challis 7	12.105366	125.040561	-104
Challis 8	12.102161	125.047823	-103
Challis 9	12.1091	125.035398	-100
Challis 10	12.126736	125.017348	-98
Challis 11	12.099143	125.054613	-101
Champagny 1	12.487223	124.312601	-70
Cockell 1	11.667278	125.039228	-265.5
Cockell 1ST1	11.667278	125.039228	-265.5
Crane 1	12.125766	125.628168	-78
Cygnet 1	11.896123	125.939029	-80
Delamere 1	12.000475	125.304193	

Delta 1	12.649066	123.970348	-205
Dillon Shoals 1	11.239264	125.446997	-125
Discorbis 1	12.882476	123.812796	-199
Drake 1	11.285013	125.835438	-103
Dromana 1	12.274998	124.9125	-96
East Swan 1	12.301968	124.582249	-103
East Swan 2	12.292674	124.583496	-104
Echuca Shoals 1	13.750342	123.723617	-194
Eclipse 1	12.271388	124.618609	-109
Eclipse 2	12.238423	124.643611	-109
Eider 1	11.389167	125.746389	-100
Fagin 1	11.571388	125.137776	
Flamingo 1	11.026111	126.481944	-96
Fulica 1	11.088891	125.875183	-136
Garganey 1	11.356651	125.91643	-100
Grebe 1	12.451111	124.249444	-69
Gryphaea 1	12.810646	123.739321	-200
Heywood 1	13.462683	124.066725	-35
Ibis 1	12.062021	125.346491	-95
Jabiru 1	11.932181	125.005222	-120
Jabiru 1A	11.933561	125.004081	-120
Jabiru 2	11.934864	124.988837	-118
Jabiru 3	11.925583	125.00885	-115
Jabiru 4	11.921625	125.019882	-119
Jabiru 5	11.940204	124.989593	-120
Jabiru 5A	11.939861	124.990171	-120
Jabiru 6	11.930321	125.012855	-118
Jabiru 7	11.920548	125.017303	-119
Jabiru 7 ST1	11.917991	125.017401	-119
Jabiru 8	11.936518	125.01038	-118
Jabiru 8A	11.936526	125.010388	-118
Jabiru 9	11.951113	124.980398	-118
Jabiru 10	11.922358	125.026016	-118
Jabiru 11	11.942079	124.993308	-118
Jarrah 1	11.289238	125.70328	-108
Jarrah 1A	11.289333	125.703166	-108
Kalyptea 1	13.032998	123.872388	-214
Katers 1	12.675416	124.744416	-90
Keeling 1	12.620576	124.165043	-189
Kite 1	12.067793	126.436761	
Londonderry 1	13.614769	124.51183	-90
Lorikeet 1	11.173676	125.617996	-108
Lucas 1	12.260361	124.133804	-90
Maple 1	12.019916	124.538716	-125
Montara 1	12.689346	124.531661	-85.1
Mount Ashmore 1	12.560276	123.20667	-623
Mount Ashmore 1A	12.560276	123.20639	-623
Mount Ashmore 1B	12.560081	123.20781	-623
Nancar 1	10.988741	125.757818	
Nome 1	11.655268	125.221291	-122
North Hibernia 1	11.671953	123.324741	-33
Octavius 1	11.847221	124.910555	-155
Oliver 1	11.644804	125.008801	-305

Osprey 1	12.219167	125.22084	-101
Paqualin 1	11.980638	124.5069	-125
Parry 1	12.270646	124.337516	-96
Pascal 1	12.203	124.221898	-100
Peewit 1	12.656144	126.020894	-85.8
Pengana 1	11.891433	125.029043	-117
Plover 1	12.7125	126.368611	-58
Plover 2	12.958056	126.174444	-59
Plover 3	12.818156	126.115833	-74.7
Pollard 1	11.664444	124.56889	
Prion 1	12.404444	124.151944	-70
Prudhoe 1	13.748819	123.864203	-175
Puffin 1	12.308333	124.333611	-102
Puffin 2	12.363056	124.275277	-78
Puffin 3	12.288783	124.35825	-98
Puffin 4	12.292226	124.360668	-98
Rainbow 1	11.937958	124.331913	-135
Rainier 1	12.062463	125.023008	-110
Rob Roy 1	13.971	124.199194	-112
Rowan 1	12.498298	124.393698	-300
Sahul Shoals 1	11.426667	124.54723	-28
Skua 1	12.505278	124.432777	-80
Skua 2	12.509516	124.404346	-81.7
Skua 3	12.506121	124.414663	-78.5
Skua 4	12.493136	124.425766	-81
Skua 5	12.473918	124.443666	-85
Skua 6	12.487498	124.438498	-82
Snowmass 1	11.994708	125.179466	-112
Swan 1	12.188056	124.492777	-109
Swan 2	12.194727	124.495677	-108
Swift 1	12.537356	124.451507	-81
Talbot 1	12.453138	124.881616	-111
Talbot 2	12.457133	124.870329	-103
Taltarni 1	12.612863	124.579529	-76
Tamar 1	11.870924	126.211144	-64
Tancred 1	11.734743	125.323429	-108
Turnstone 1	11.736944	125.295833	-118
Voltaire 1	11.193351	125.331983	-331
Vulcan 1	12.241993	124.549474	-108
Vulcan 1A	12.242261	124.549964	-108
Vulcan 1B	12.242642	124.550339	-109
Whimbrel 1	12.482778	125.378055	-77
Willeroo 1	12.027721	124.897891	-114
Woodbine 1	12.645206	124.147072	-189
Yering 1	12.612888	124.517098	