AGSO

HIGH RESOLUTION SEISMIC SURVEY OF THE NORTHERN CARNARVON BASIN, NORTH WEST SHELF, AUSTRALIA: SURVEY 136 POST-CRUISE REPORT

BY K.K. ROMINE, G. CASSIM & SURVEY 136 SHIPBOARD PARTY

RECORD 1995/17

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Marine, Petroleum and Sedimentary Resources Program

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CONTENTS

APPENDICES

FIGURES

EXECUTIVE SUMMARY

The Carnarvon Cretaceous-Tertiary Tie seismic survey (Survey 136) has acquired a high-quality, high-resolution seismic dataset for the Tertiary and Cretaceous section in the northern Carnarvon Basin. These data were acquired as part of the Continental Margins Program North West Shelf Study, whose mission is "to improve the understanding of the basin and margin evolution of the North West Shelf in order to stimulate resource exploration, improve exploration efficiency and effectiveness, and support government decision-making in resource management". One of the critical issues in the northern Carnarvon Basin and Timor Sea area is an understanding of the hydrocarbon migration history. Many discoveries and fields in both areas have residual oil columns or underfilled reservoirs of Early Cretaceous age and older. The leakage and migration of hydrocarbons is directly linked to the reactivation of existing faults and fault systems during a Miocene-age tectonic event (O'Brien et al., 1993). The Tertiary gas discovery at Maitland 1 in the northern Carnarvon Basin (Sit et al., 1994) raises a fundamental question, i.e. what is the potential for oil and gas leaked from older reservoirs to be retrapped in younger, Late Cretaceous and Tertiary reservoirs. To gain an understanding of the distribution and potential migration history for hydrocarbons in the northern Carnarvon Basin, the following objectives will be addressed utilizing the high resolution Carnarvon Cretaceous-Tertiary Tie survey:

- construction of a regional, sequence-based chronostratigraphic framework for the Cretaceous and Tertiary, within which the occurrence and distribution of potential seal and reservoir facies may be analyzed and predicted;

- assessment of the post-Valanginian fault reactivation history of the northern Carnarvon Basin and the implications for: (a) the migration of hydrocarbons from pre-Cretaceous traps and (b) the integrity of potential Cretaceous and Tertiary seals; and

- determination of the probability of secondary migration and entrapment of hydrocarbons within Cretaceous and Tertiary strata.

To address these objectives, a regional grid of 24 strike and dip lines that tie 96 wells has been acquired in the Exmouth, Barrow, Dampier and Beagle Sub-basins, using the R/V *Rig Seismic*. The data were recorded using Seismic Systems Inc GI airguns (19.66 liter, 8-gun array) and with the following parameters: 3000m streamer length; 12.5m group interval; 18.75 shot interval; 2ms sample interval; 5.5sec record length; and 8000% effective fold. The pre-planned survey was completed with a few days to spare, and an additional 4 lines totalling 335km were acquired to the south of the study area as the ship proceeded to port. The recording parameters for these lines were altered as follows: 25m shot interval; 8.0sec record length; and 6000% effective fold. The total seismic coverage for Survey 136 was 4220km.

INTRODUCTION

Since 1988, exploration success in the northern Carnarvon Basin (Fig. 1) has increased Australia's estimated reserves by 35%, providing the most significant discoveries since those of the Gippsland Basin (Purcell & Purcell, 1994). In some parts of the basin there are small, or underfilled reservoirs (e.g., West Muiron; Mitchelmore & Smith, 1994), or discoveries that have sampled only residual oil columns (e.g. Leatherback; Bauer et al., 1994). In each example, a Miocene tectonic compressional event is invoked to explain the reactivation of faults and subsequent migration and leakage of hydrocarbons. Residual oil accumulations also have been documented in the Timor Sea (Whibley & Jacobson, 1990). In the Cartier Trough of the Vulcan Sub-basin, analysis of oil-filled fluid inclusions (Lisk & Eadington, 1994) has demonstrated that the most recent phase of oil migration was initiated in the Miocene, as in the northern Carnarvon Basin. The compressional tectonic event responsible for reactivation of faults and oil migration has been related to collision and subduction along the northern boundary of the Australian continent during the Miocene (O'Brien et al., 1993). This event is the most recent in a series of tectonic events which have governed the sedimentary and structural history of the North West Shelf basins (AGSO North West Shelf Study Group, 1994).

As part of its research program on the North West Shelf, the Marine, Sedimentary and Petroleum Resources Program of AGSO has acquired regional deep-seismic data across and between the major sedimentary basins, in order to determine the linkages between the major structural elements and to facilitate the development of a regionally integrated structural and tectonic history for the region. Interpretation of these data demonstrate that the reactivation history of structures in North West Shelf basins has had a fundamental impact on the distribution of hydrocarbons. Building on the tectonic and structural framework provided by the deep-seismic data, Survey 136 provides the necessary resolution to examine the Cretaceous and Tertiary section in the northern Carnarvon Basin in an effort to develop an understanding of the migration history of hydrocarbons and to investigate the likelihood that hydrocarbons leaked from older traps may be reservoired in younger rocks.

EXPLORATION HISTORY*

The initial oil exploration permits on the North West Shelf were granted to Ampol Petroleum Ltd in 1946. While these leases were primarily onshore, they did cover the offshore Carnarvon Basin out to a water depth of 100 fathoms (~183 m). In 1952, Ampol combined with Caltex to form West Australian Petroleum Pty Ltd (Wapet), and the new company drilled its first well (Cape Range 1) on a surface anticline in 1953. This well flowed oil from a small pool and provided a major impetus to exploration on the southern North West Shelf.

The first offshore seismic work was carried out by Wapet in 1961. In 1964, Wapet drilled a wildcat well on Barrow Island that discovered oil in Upper Jurassic sands. Subsequent appraisal drilling on Barrow Island showed the presence of a major oil field, principally reservoired in Cretaceous sands. In 1965, Wapet was granted acreage west of Barrow Island. At about the same time, Woodside (Lakes Entrance) Oil Co. (subsequently to become Woodside Petroleum) and associated companies were granted leases to the north and offshore from the Wapet leases. This general delineation of

* Excerpted and modified from Stagg, 1992.

operations has persisted since the 1960's, with Wapet being considered the principal explorer in the Barrow Sub-basin, while Woodside is considered to be the prime explorer in the Dampier Sub-basin.

In 1968, Woodside made a non-commercial oil discovery at Legendre 1 on the landward flank of the Dampier Sub-basin. The major Woodside successes came in 1971, with major discoveries of gas/condensate at North Rankin 1, Goodwyn 1, and Angel 1 within or overlying fault blocks of the Rankin Platform (Fig. 2). Wapet continued the run of success on the Rankin Platform with the discovery of a major gas/condensate field in the Gorgon structure at the southwestern extremity of the platform in 1980.

Since the early 1970s, as the full potential of the North West Shelf has become apparent, exploration lease sizes have been steadily reduced and more players have become involved in exploration. During the 1980s, there have been a number of small- to medium-scale commercial and sub-commercial oil discoveries in both the Barrow and Dampier Sub-basins (eg Harriet, Talisman, Saladin, Roller, Wanaea, Cossack, Ramillies, Wandoo). At the time of writing, there are 15 operators active in the northern Carnarvon Basin (Appendix 1).

NOTE: A summary of the structure, stratigraphy, tectonic framework and hydrocarbon accumulations for the northern Carnarvon Basin is included as Appendix 2.

GENERAL OBJECTIVES

The high-resolution seismic dataset provides the basis for a study which has the following objectives:

- construction of a regional, sequence-based chronostratigraphic framework for the Cretaceous and Tertiary within which the occurrence and distribution of potential seal and reservoir facies may be analyzed and predicted;

- assessment of the post-Valanginian fault reactivation history of the northern Carnarvon Basin and the implications for: (a) the migration of hydrocarbons from pre-Cretaceous traps and (b) the integrity of potential Cretaceous and Tertiary seals;

- determination of the probability of secondary migration and entrapment of hydrocarbons within Cretaceous and Tertiary strata.

The existence of residual oil columns in the Timor Sea basins and the northern Carnarvon has been recognized for some time. However, there has been little effort spent investigating where the missing portions of the original hydrocarbon accumulations have gone. Studies presented recently provide evidence for migration of older hydrocarbons through Jurassic and Cretaceous strata (Lisk & Eadington, 1994; Ellis et al., 1994). In fact, the recent discovery of hydrocarbons in the lowermost Tertiary (Sit et al., 1994) has provided a new play concept for the northern Carnarvon Basin, and has highlighted the potential for hydrocarbon accumulations in younger-than-traditional targets. This discovery provided the impetus for acquiring this high resolution survey, Survey 136, to investigate the potential of younger traps to reservoir hydrocarbons after secondary migration.

SURVEY PARAMETERS AND ACQUISITION DETAILS

The research vessel *Rig Seismic* (Appendix 3) departed Port Hedland on October 14th, 1994 and arrived at the end of the survey in Fremantle on November 15th, 1994. The shipboard party (Appendix 4) comprised 15 AGSO personnel making up the seismic crew and 15 AMSA personnel on the marine crew.

Data acquired

Way points for Survey 136 are provided in Appendix 5. Data coverage in the main survey area comprises 18 dip lines, 4 regional strike lines and 2 short strike lines positioned to tie specific wells (Fig. 3). These data were acquired using a single 19.66 liter GI gun array with an 18.75m shot interval and a 3000m streamer with a hydrophone group interval of 12.5m (240 active groups). The CDP fold is 8000% and the record length is 5.5 seconds. The main survey was completed early and four additional lines south of the main area were collected on the way to port in Fremantle. These lines consist of three in the dip direction and one along strike (Fig. 4). The parameters for acquisition were altered to a record length of 8.0 seconds, a shot interval of 25m and 6000% CDP fold.

Seismic program

The program, in general, was executed as planned (Romine, 1994) with the exception of the additional four lines at the end of the survey. Several dip lines and one strike line were truncated or altered due to shallow water depths. Many of the well tie locations were occupied by rigs or platforms and the seismic lines deviate slightly around them. However, the number of wells tied is very high (96; Appendix 6) and will be a major asset to the study.

Cruise Narrative

The Carnarvon Cretaceous-Tertiary Tie cruise (Survey 136) commenced on departure from Port Hedland on October 14th, 1994 and ended on arrival in Fremantle on November 15th, 1994. The streamer was deployed on October 15th and retrieved for transit to port on November 13th. The first seismic production occurred on October 17th with line 136/1900. The following narrative details the progress of the survey.

14 October: Sailed from Port Hedland towards streamer laying area.
15 October: Streamer deployed and balanced; guns tested.
16 October: Continued checking for bad channels.
17 October: Streamer out, guns deployed; began shooting line 136/1900; tied wellhead Nebo 1; LSP at 5880. Daily total of 108.4km
18 October: Continuing line 136/1900; FSP 136/1900/5881; tied wells Ronsard 1, Sable 1, Finucane 1 and Bounty 1; LSP 136/1900/9144; change of line direction (dog-leg), beginning next line segment with FSP 136/1901/9054; tied wells Eaglehawk 1, Miller 1, North Rankin 1, Goodwyn 7, Goodwyn 8, Goodwyn 2, Echo 1 and Malus 1; LSP at 136/1901/8511. Daily total of 218.9km.

19 October	FSP 136/1901/8512; tied wells N. Tryal Rocks 1, Sultan 1, W. Tryal Rocks 3, Bluebell 1, veered off line to avoid drilling ship and missed tie to N. Gorgon 1, tied Central Gorgon 1, Zeepaard 1 and Resolution 1. EOL 136/1901/21504. Daily total of 243.6km.
20 October	SOL 136/0100; tied wells Zeewulf 1, Resolution 1; EOL 136/0100. SOL 136/0200; tied wells W. Muiron 2, 3 and 4. LSP 136/0200/2453. Daily total of 130.5km.
21 October	FSP 136/0200/2454; tied Novara 1; EOL 136/0200. SOL 136/0300; tied Outtrim 1; LSP 136/0300/6978. Daily total of 203.1km.
22 October	Continuing 136/0300; tied Hawksbill 1; EOL 136/0300. Did not shoot proposed southern end of line 136/2100 due to shallow water. SOL 136/2100; tied Outtrim 1; line 136/2100 temporarily suspended at LSP 136/2100/2003. SOL 136/0400; tied Somerville 1 and Anchor 1; inboard leg aborted due to shallow water; line continued on outboard leg as 136/0401; retied Somerville 1; line temporarily suspended for completion of 136/2100. SOL FSP 136/2101/2916; tied Griffin 1 and Hilda 1A; EOL 136/2101. Returned to 136/0400; SOL FSP 136/0402/3193; tied Ramillies 1; LSP 136/0402/4053. Daily total of 110.7km.
23 October	FSP 136/0402/4054; tied Zeepaard 1; EOL 136/0402. SOL 136/0500; tied Minden 1; LSP 136/0500/5767. Daily total of 215.2km.
24 October	FSP 136/0500/5768; tied Rosily 1a; EOL 136/0500. SOL 136/0600; tied Kurrajong 1, Spar 1, deviated around N. Gorgon 1 platform; streamer balance problem, line suspended, LSP at 136/0600/6730. Daily total 147.2km.
25 October	Continuing line with FSP 136/0601/6940; EOL LSP 136/0601/8447. SOL 136/0700; tied W. Tryal Rocks 3, W. Tryal Rocks 2, Maitland 1 and W. Pepper 1; LSP 136/0700/8158. Daily total of 177.7km.
26 October	FSP 136/0700/8159; line deviation to avoid exclusion zone of Chervil 3 platform; EOL 136/0700. Rendezvous with helicopter for personnel exchange. SOL 136/0800; tied Sultan 1; EOL 136/0800. Daily total of 113.5km.
27 October	SOL 136/0900; tied Forrest 1A and Flag 1 before line suspended due to shallow water; continuation of line as new segment with some adjustments to way points - SOL 136/0901; line deviation through Harriet Field platforms; Harriet 1 wellhead 1107m offline; EOL 136/0901. Transit to 136/2000. Daily total of 140.3km.
28 October	SOL 136/2000; tied Forrest 1A, Maitland 1, East Spar 2 (372m offline); line suspended for several hours due to engine problems; continuation of line - SOL 136/2001; tied Minden 1 and York 1. Daily total of 163.2km.
29 October	Continuation of 136/2001; tied Vlaming Head 1 and Novara 1; EOL 136/2001. SOL 136/2200; tied Rosily 1A. Daily total of 156.8km.
30 October	EOL 136/2200. SOL 136/2300; tied Venture 1, Wilcox 1 and 2, Fisher 1, Rankin 1, Dockrell 1, Pueblo 1 and Tidepole 1; EOL 136/2300. Transit to 136/1100. Daily total of 114.6km.
31 October	SOL 136/1000; tied Rankin 1, Dixon 1, Stag 1 (165m offline); EOL 136/1000. SOL 136/1100; tied Enderby 1, Montebello 1, Dampier 1; LSP 136/1100/4414. Daily total of 207.3km.
1 November	FSP 136/1100/4415; tied Goodwyn 3 and 6; EOL 136/1100. Transit to 136/1200 and compressor maintenance. SOL 136/1200; tied Gandara 1, N. Rankin 6 and 5, Miller 1, line suspended for gun maintenance. Daily total of 145.0km.

2 November	Continuation of 136/1200. SOL FSP 136/1201/5314; tied Orion 1; EOL 136/1201. SOL 136/1300; tied Lewis 1A, Baleena 1, and Wanea 5; LSP 136/1300/7497. Daily total of 191.2km.
3 November	EOL 136/1300. SOL 136/1400; gun problems, circled; SOL 136/1401; tied Angel 2, Forestier 1 and Cygnus 1; EOL 136/1401. Daily total of 121.8km.
4 November	SOL 136/1500; tied Hauy 1, Talisman 1, Finucane 1; EOL 136/1500. SOL 136/1600; tied Sable 1 and Aurora 1; LSP 136/1600/4721. Daily total of 222.7 km.
5 November	FSP 136/1600/4722; tied De Grey 1; EOL 136/1600. SOL 136/2002 (continuation of line 136/2000 and 136/2001 from 28-29 October); tied Angel 2 and 1A, deviation around Cossack 1 (1552m), Wanaea 3, 1 and 2, Madeleine 1, Dampier 1 and Withnell 1; EOL 136/2002. Daily total of 181.3km.
6 November	SOL 136/2400; deviation around Campbell platform, wellhead Campbell 2 641m offline; tied Rosemary 1, Rosemary North 1, Baleena 1, Samson 1, Legendre 1 and 2, Forestier 1, Nelson Rocks 1, Talisman 2 and 1, Alpha North 1, and Cossigny 1; LSP 136/2400/12951. Daily total of 238.2km.
7 November	FSP 136/2400/12952; tied North Turtle 1; EOL 136/2400. SOL 136/1800; tied Depuch 1 and Nebo 1; EOL 136/1800. Daily total of 189.6km.
8 November	SOL 136/1700; EOL 136/1700. Completion of main survey. Retrieved guns and streamer. Transit to southern end of main survey to begin additional lines. Daily total of 146.4km.
9 November	Transit to line 136/2500. Deployment of streamer, checking and maintenance.
10 November	SOL 136/2500; tied Resolution 1; LSP 136/2500/2176. Daily total of 52.4km.
11 November	FSP 136/2500/2177; line 136/2500 temporarily suspended to shoot 3 dip lines. SOL 136/2800; EOL 136/2800/1362. SOL 136/2700; EOL 136/2700/1538. SOL 136/2600; LSP 136/2600/1412. Daily total of 135.5km.
12 November	FSP 136/2600/1413; EOL 136/2600. Continuation of line 136/2500 as 136/2501; LSP 136/2501/9762. Daily total of 139.1km.
13 November	FSP 136/2501/9763; tied Pendock 1; EOL 136/2501. Retrieved guns, magnetometer and streamer. Transit to Fremantle. Daily total of 8.1km.
15 November	Arrival at Fremantle. End of survey

Seismic Data Recorded

A total of 28 lines were recorded on Survey 136 (Figs 3 & 4). The main survey production totalled 3885km (Figs 5 & 6), and with the additional 335km of the additional lines to the south, makes a total of 4220km. The survey ties into AGSO deep seismic surveys 101 and 110 (Romine, 1994, Fig. 9).

LINE 136/01(0100)
Dip line - NNW-SSE, crosses the southern end of the Exmouth Sub-basin intersecting AGSO deep seismic (DS) lines 110/11, 101/16 and 101/5. Ties Zeewulf 1 and Resolution 1 and survey 136 lines 19(1900) and 20(2000).

LINE 136/02(0200)
Dip line - Southern Exmouth Sub-Basin. Intersects AGSO DS lines 101/16, 110/11 and 101/4. Ties Novara 1, West Muiron 2, 3, and 4 and survey 136 lines 19(1900), 20(2000) and 21(2100).

LINE 136/03(0300)
Dip line - Central Exmouth Sub-basin; southern end of line crosses Long Island Fault System and Rough Range Fault. Intersects AGSO DS lines 101/16, 110/12, 101/4 and 110/11. Ties Outtrim 1 and Hawksbill 1, and survey 136 lines 19(1900), 20(2000), and 21(2100).

LINE 136/04(0400)
Dip line - Northern Exmouth Sub-basin, crosses the Alpha Arch and the southern end of the Barrow Sub-basin. Intersects AGSO DS lines 110/08, 101/6, 101/4 and 110/12. Ties Zeepaard 1, Ramillies 1, Somerville 1 and Anchor 1, and survey 136 lines 19(1900), 20(2000), 21(2100) and 22(2200).

LINE 136/05(0500)
Dip line - From northern end of Exmouth Sub-basin, crosses the Alpha Arch/Rankin Fault System and the southern Barrow Sub-basin. Intersects AGSO DS lines 110/8, 101/7, 101/4 and 101/6. Ties Minden 1 and Rosily 1A and survey 136 lines 19(1900), 20(2000) and 22(2200).

LINE 136/06(0600)
Dip line - Southern end of the Rankin Platform, across the Rankin Fault System and the Barrow Sub-basin. Intersects AGSO DS lines 110/8, 101/7 and 101/4. Ties Spar 1 and Kurrajong 1 and survey 136 lines 19(1900), 20(2000) and 22(2200).

LINE 136/07(0700)
Dip line - Southern Rankin Platform, across the Rankin Fault System and central Barrow Sub-basin. Intersects AGSO DS lines 110/8, 110/9, 101/3, 101/2 and 101/7. Ties West Tryal Rocks 2 and 3, Maitland 1, West Pepper 1 and Chervil 3 and survey 136 lines 19(1900), 20(2000) and 22(2200).

LINE 136/08(0800)
Dip line - From the Rankin Platform across the northern Barrow Sub-basin, ending just north of Barrow Island. Intersects AGSO DS lines 110/8, 110/9 and 101/2. Ties Sultan 1 and survey 136 lines 19, 20 and 23.

LINE 136/09(0900)
Dip line - From the Rankin Platform, crosses the possible accommodation zone that separates the Barrow and Dampier Sub-basins. Intersects AGSO DS line 110/8. Ties Forrest 1A, Flag 1, and Georgette 1 and survey 136 lines 19(1900), 20(2000), 23(2300) and 24(2400).

LINE 136/10(1000)
Dip line - From the Rankin Platform across the southern end of the Dampier Sub-basin. Intersects AGSO DS lines 110/8 and 101/2. Ties Rankin 1, Dixon 1, and Stag 1, and HIREZ lines 19(1900), 20(2000), 23(2300) and 24(2400).

LINE 136/11(1100)
Dip line - From the Rankin Platform across the southern Dampier Sub-basin and southern Enderby Trend. Intersects AGSO DS lines 110/8 and 101/2. Ties Goodwyn 3 and 6, Dampier 1, Montebello 1 and Enderby 1, and survey 136 lines 19(1900), 20(2000), 23(2300) and 24(2400).

LINE 136/12(1200)
Dip line - From the Rankin Platform, across the central Dampier Sub-basin and Enderby Trend. Intersects AGSO DS lines 110/8 and 101/2. Ties Gandara 1, North Rankin 5 and 6, Miller 1 and Orion 1, and survey136 lines 19(1900), 20(2000) and 24(2400).

LINE 136/13(1300)
Dip line - From the Rankin Platform, across the central Dampier Sub-basin and Enderby Trend. Intersects AGSO DS lines 110/8 and 101/2. Ties Wanaea 5, Baleena 1, and Lewis 1A, and survey 136 lines 19(1900), 20(2000) and 24(2400).

LINE 136/14(1400)
Dip line - From the Rankin Platform, crosses the northern Dampier Sub-basin and Enderby Trend. Intersects AGSO DS lines 110/8 and 110/2. Ties Angel 2, Forestier 1 and Cygnus 1, and survey 136 lines 19(1900), 20(2000) and 24(2400).

LINE 136/15(1500)
Dip line - Northern Rankin Platform, crosses the northern end of the Dampier Sub-basin and Enderby Trend, and ends on the Lambert Shelf. Intersects AGSO DS lines 110/8 and 110/2. Ties Finucane 1, Talisman 1 and Hauy 1, and survey 136 lines 19(1900), 20(2000) and 24(2400).

LINE 136/16(1600)
Dip line - Northern end of Rankin Platform, crosses possible accommodation zone between the Dampier and Beagle Sub-basins, and ends on the southern flank of De Grey Nose. Intersects AGSO DS lines 110/8 and 110/1. Ties Sable 1, Aurora 1 and De Grey 1, and survey 136 lines 19(1900) and 24(2400).

LINE 136/17(1700)
Dip line - Western Beagle Sub-basin, crosses Cossigny Trough and ends on the Lambert Shelf. Intersects AGSO DS lines 110/8, 110/1 and 110/4. Ties survey 136 lines 19(1900) and 24(2400).

LINE 136/18(1800)
Dip line - NW-SE across the Beagle Sub-basin, crosses the Beagle Trough and ends west of the North Turtle Hinge. Intersects AGSO DS lines110/8, 110/4 and 110/1. Ties Nebo 1 and Depuch 1, and survey 136 lines 19(1900) and 24(2400).

LINE 136/19(1900)
Strike line - Along the northwestern flank of the Exmouth Sub-basin, the southeastern edge of the Rankin Platform, the northwestern flank of the Dampier Sub-basin and into the Beagle Sub-basin along the northern flank of the Cossigny and Beagle Troughs. Intersects AGSO DS lines 110/11, 110/12, 101/6, 101/7, 110/9, 101/8, 101/9, 101/10, 110/3, 110/2 and 110/7. Ties Resolution 1, Zeepaard 1, Central Gorgon 1, Bluebell 1, West Tryal Rocks 3, Sultan 1, North Tryal Rocks 1, Malus 1, Echo 1, Goodwyn 2, 7 and 8, North Rankin 1, Miller 1, Eaglehawk 1, Bounty 1, Finucane 1, Sable 1, Ronsard 1 and Nebo 1. Ties survey 136 dip lines 1(0100) through 18(1800).

LINE 136/20(2000)
Strike line - Follows the southeastern flank of the Exmouth Sub-basin, crosses the Alpha Arch into the northwestern Barrow Sub-basin, and continues along the northwestern flank of the Lewis

Trough (Dampier Sub-basin). Intersects AGSO DS lines 101/5, 110/11, 110/12, 101/6, 101/7, 101/3, 101/2, 101/8, 101/9 and 101/10. Ties Novara 1, Vlaming Head 1, York 1, Minden 1, East Spar 2, Maitland 1, Forrest 1A, Withnell 1, Dampier 1, Madeleine 1, Wanaea 2 and 3, Angel 1A and 2, and survey 136 lines 1(0100) through 15(1500).

LINE 136/21(2100)
Strike line - Between the Exmouth and Barrow Sub-basins. Intersects AGSO DS lines 110/11, 110/12 and 101/4. Ties Outtrim 1, Griffin 1 and Hilda 1A and survey 136 lines 2(0200), 3(0300) and 4(0400).

LINE 136/22(2200)
Strike line - Parallel to the Barrow Sub-basin depositional axis and ends on the northwest side of Barrow Island. Intersects AGSO DS lines 110/12, 101/6, 101/7. Ties Rosily 1A and survey 136 dip lines 4(0400) through 7(0700).

LINE 136/23(2300)
Strike line - Northeast flank of the southern Dampier Sub-basin. Intersects AGSO DS lines 110/9 and 101/8. Ties Venture 1, Wilcox 1, Wilcox 2, Fisher 1, Rankin 1, Dockrell 1, Pueblo 1 and Tidepole 1, and survey 136 dip lines 8(0800) through 11(1100).

LINE 136/24(2400)
Strike line - Originally, this line was the northeastern portion of line 22, but line 22 had to be split because of shallow water between Barrow Island and the Montebello Islands. Line 24 begins northeast of the Montebello Islands (northeast of Barrow Island) in the transition zone between the Barrow and Dampier Sub-basins and continues parallel to the southeastern flank of the Dampier and Beagle depocentres (troughs). Intersects AGSO DS lines 101/8, 101/9, 101/10, 110/3, 110/2, 110/4 and 110/1. Ties Flag 1, Campbell 2, Rosemary 1, Rosemary North 1, Baleena 1, Samson 1, Legendre 1, Legendre 2, Forestier 1, Nelson Rocks 1, Talisman 2, Talisman 1, Alpha North 1, Cossigny 1 and North Turtle 1. Ties survey 136 dip lines 9(0900) through 18(1800).

LINE 136/25(2500)
Strike line - Begins in the Exmouth Sub-Basin at the tie to Resolution 1 on line 136/01 and parallels the West Australian coast until the tie at Pendock 1. Ties AGSO DS line101/05 and 136/01(0100) and 136/19(1900).

LINES 136/26(2600), 136/27(2700), 136/28(2800)
Dip lines perpendicular to the coastline and just to the south of the main, high resolution survey data. Ties only to 136/25. No well ties.

Acquisition parameters and equipment used on this cruise are included in Appendices 7 and 8. A listing of seismic tapes is provided in Appendix 9.

EQUIPMENT AND SYSTEMS REPORT
(condensed from Cruise 136 Operational Report prepared by G. Cassim)

Navigation and Positioning

Positioning of the vessel was achieved using Racal Multifix I and Multifix II Differential Global Positioning Systems (DGPS). Information from the DGPS was passed to the DAS Navigation System to position the vessel and trailing equipment with an accuracy of better than 5 metres.

The positioning of the outboard equipment was achieved with a combination of the following sub-systems:

1 - Gun Near-field Phones and Streamer Water-Break Phone: used to determine the relative positions of the streamer and gun strings. The near-field phones were also used to synchronize the firing times of the guns.

2 - Syntron Cable Compasses: 5 of these were mounted at predetermined positions along the streamer to provide data for calculation of streamer shape and feather angle during the survey.

3 - GPS Active Tailbuoy: used to determine the position of the tail of the streamer

Some software problems, combined with antenna problems and the survey layout affected the navigation throughout the cruise. The main problems were:

1 - Multi-fix II showed large noise spikes every 15-20 minutes.

2 - The Racal antennas were affected by Satcom usage, with low signal-to-noise ratios or complete receiver drop-outs when transmitting on the Satcom system.

3 - When dropping from Racal 1, to Racal 2 and on to DR (dead reckoning) navigation during times of interference from the Satcom system, the DAS sysem showed large speed variations and position jumps. This resulted in missed and out-of-sync shotpoints.

4 - Many spikes occurred on the navigation strip charts on and off for the duration of the cruise. There was no effect on vessel positioning, but the charts were less useful for normal quality control.

5 - Turning points on lines in the survey occurred at wellheads. Initially, these were handled by travelling half the streamer length past the 'dogleg' point before turning onto the next line segment. However, this technique resulted in shotpoint numbering problems the navigation system is not designed to handle.

6 - Problems with 'doglegs' also occurred due to the small windows the MUSIC recording system uses to keep the speed in check. An apparent drop in speed

occurred each time the navigation system switched to the next line segment following a dogleg.

Steps were taken in each case to minimize the effects of these problems, however, it has been recommended that the DAS software be upgraded.

Gravity

Gravity was recorded with a Bodenseewerk Geosystem KSS-31 Marine Gravity Meter. This unit only worked for the first two-thirds of the survey, apparently due to worn bearings in the gyro.

Magnetics

Magnetic field data was collected throughout the survey by a Geometrics G801/G803 Magnetometer. The system worked fairly well throughout the survey.

Bathymetry

Raytheon CESP I, 3.5 kHz and 12 kHz echo sounders recorded bathymetric data during the survey. Water depths for much of the survey were less than 200 metres and for the inboard ends of many of the dip lines were as shallow as 20 metres.

Seismic Acquisition System

Recording system

Seismic recording systems generally worked well throughout the cruise. Few problems were experienced with tapes, drives, amplifiers, A/D converter and electronics. Shotpoint numbering problems, as mentioned previously, resulted in part from some deficiencies within the software of the navigation system.

Streamer

Streamer configuration is shown in Fig. 7. The cable was held at a depth of 5 to 6 metres for the main survey and at 12 metres for the last four lines collected at the end of the cruise.

The streamer performed well during the cruise. Early in the cruise there was a problem with failure of the cable leveller batteries, but the replacements performed much longer than the unusually short-lived first batch, eliminating that problem. Streamer balance was good for most of the survey, only suffering abnormal amplitude variation during the last few days of the cruise during bad weather.

Tailbuoy

The tailbuoy worked throughout the survey although water in a BNC connection caused a low VHF signal to be transmitted for most of the first part of the survey. By the end of the survey, the tailbuoy GPS transmission was working smoothly.

Seismic source

Airguns

The seismic source was provided by a single 19.66 liter (1200 cu.-in.) GI gun array consisting of eight 2.46 liter (150 cu.-in.) guns. The GI guns performed extremelly well during the survey. Timing remained better than +/- 1.0 millisecond with few misfire or timing errors.

Compressors

There were many problems during the cruise with the compressors, at times requiring the firing of only 7 of the 8 GI guns in order to maintain at least 1750 psi during periods when some compressors were disabled.

PRELIMINARY RESULTS

An example of the new dataset with preliminary processing is illustrated in Fig. 8. The peak frequency in the data has increased from a more conventional 15-25 cps to approximately 50-65 cps. This frequency content translates to a bed resolution of less than 10m (siliclastics) - 20m (carbonates), rather than the more usual 30 - 60m, respectively. This level of resolution is optimal for the identification and delineation of relatively thin, but significant, reservoir, source and seal units in detailed sequence stratigraphic studies.

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APPENDIX 1

OPERATORS OF PERMITS AND LICENSES IN THE SURVEY AREA

Ampolex Limited
Broken Hill Petroleum Prop. Ltd.
Carnarvon Petroleum NL
Discovery Petroleum NL
Hadson Energy Ltd.
Kufpec Australia
Marathon Petroleum Western Australia Ltd.
MIM Petroleum Exploration Prop. Ltd.
Mobil Exploration & Producing Australia Prop. Ltd.
Phillips Oil Company Australia
Plains Resources International
Seafield Resources PLC
West Australian Petroleum (WAPET) Prop. Ltd.
Western Mining Corp. Ltd.
Woodside OffshorePetroleum Prop. Ltd.

APPENDIX 2

STRUCTURE, STRATIGRAPHY, TECTONIC FRAMEWORK AND HYDROCARBON ACCUMULATIONS OF THE NORTHERN CARNARVON BASIN

(See Romine, 1994)

STRUCTURE

The gross structure of the North West Shelf comprises a series of generally NE-SW trending rifted Mesozoic depocentres overlying Palaeozoic NW-SE trending basins that may have constituted failed arms of an incipient rift system (Veevers, 1988). Within the northern Carnarvon Basin, the four principal shelf and upper slope depocentres - the Exmouth, Barrow, Dampier, and Beagle Sub-basins (Fig. 8) - accumulated most of their sedimentary fill in the Triassic and Jurassic, before the rift system aborted with the separation of Australia from (?)Greater India along a parallel rift system along the northwest and northern margins of the Exmouth Plateau. Although the four sub-basins have frequently been treated as separate entities in the literature, this is largely due to the concentration of individual exploration companies in one or other of the sub-basins. In fact, the sub-basins are very closely related, particularly in the case of the Barrow and Dampier Sub-basins, and any analysis of the basin-forming mechanisms of the area should consider all of them together.

BOUNDARIES BETWEEN SUB-BASINS

The boundaries between the sub-basins of the southern North West Shelf are complex and not well-imaged or well-understood. In the southwest, the Exmouth Sub-basin is in *en echelon* arrangement with the Barrow Sub-basin (e.g., see figure 2 in Barber, 1988), with the boundary between the two usually being taken as the southern extension of the Rankin Trend (Alpha Arch) and the E-W trending Long Island Fault System (Fig. 9). The junction between the Barrow and Dampier Sub-basins, northeast of Barrow Island, is defined largely on the basis of a change in strike of the main depocentres, from NNE-SSW in the Barrow Sub-basin to NE- SW in the Dampier Sub-basin. This complex junction is not imaged at depth, but probably overlies a broad NW-SE trending transfer fault zone.

In the northeast, the boundary between the Dampier and Beagle Sub-basins is taken at a feature that has been referred to as the 'De Grey Nose'. This feature is probably also a complex transfer fault zone that truncates the northeastern end of the Dampier Sub-basin. To the northeast, the Beagle Sub-basin, as with the Exmouth Sub-basin, is relatively poorly known, mainly because of the lack of exploration success and the commensurate lack of modern high-quality seismic data. It appears from published tectonic elements maps and papers that the Mesozoic trend of the Beagle Sub-basin is strongly influenced by underlying orthogonal trends of the Offshore Canning Basin (the Roebuck Basin of Hocking, 1994), and in some reports it has been considered to be a Mesozoic sub-basin of the Canning Basin, as with the Rowley and Bedout Sub-basins. The Beagle Sub-basin is separated from the Bedout Sub-basin, Bedout High, and Rowley Sub-basin to the east and northeast by the N-S trending North Turtle Hinge.

INTERNAL SUB-BASIN STRUCTURES (Fig. 9)

To the southeast, the main depocentres of the rift are bound by the Flinders Fault System in the south and the *en echelon* Rosemary Fault System in the north. However, the main rift- bounding faults are more properly the Scholl Island Fault in the south and the Hauy Fault System in the north. Between these two fault systems (Flinders-Rosemary and Scholl Island-Hauy), is a complex fault zone which principally includes Triassic and Permo-Carboniferous sediments. This area of the North West Shelf is one of the few areas where the Triassic-Jurassic section is thin enough that basin-forming structures can be distinguished with conventional seismic data.

Oceanwards of the Flinders and Rosemary Fault Systems, and partially overlying them, is a complex zone where Cretaceous reactivation of pre-existing structures has caused extensive faulting and buckling of the Mesozoic section. This zone hosts the Saladin, Roller, and Yammaderry Fields in the Barrow Sub-basin and includes the oil-prone Legendre Trend in the Dampier Sub-basin.

The major Mesozoic depocentres include the sinuous and generally NNE-SSW trending Barrow Depocentre in the Barrow Sub-basin and the more linear NE-SW trending Lewis Trough in the Dampier Sub-basin. Both depocentres are deep (~3 km Tertiary-Cretaceous and >5 km Jurassic, underlain by an unknown thickness of Triassic and Palaeozoics) and relatively unfaulted downwarps.

The seaward boundary of the Barrow-Dampier rift is formed by the structurally high Rankin Platform. The Rankin 'Trend' follows the southeastern edge of the Exmouth Plateau/Rankin Platform megacrustal block (Woodside, 1988). The Rankin Platform has the strongest gravity signature on the southern North West Shelf and is a fundamental structure of the rift system, as well as being host to the largest hydrocarbon reservoirs. For much of its length, the Rankin Platform is strongly fault-segmented, consisting of a series of NNE-trending pivotal Triassic horsts and grabens in an *en echelon* arrangement, suggesting that the trend formed in response to strike-slip movements (Woodside, 1988).

In the southwest, offshore from the Barrow Sub-basin, the Rankin Platform swings round to the south, where it becomes known as the Alpha Arch (which includes the large Gorgon gas field). While the deep structure of the Alpha Arch is probably less well-known than that of the Rankin Trend, its gravity expression is as strong as that of the Rankin Platform, and it also appears to represent a fundamental basin-forming structure.

The southeast boundary of the Exmouth Sub-basin is formed by the Rough Range Fault, while the northwest boundary is ill-defined, due to the scarcity of seismic data northwest of Northwest Cape. The deep structure of the Exmouth Sub-basin consists of a series of east- tilted fault blocks that are down-thrown to the west by as much as 3000 m in the pre- Cretaceous and show evidence of some reverse movement in the late Miocene (Parry & Smith, 1988).

As with the Exmouth Sub-basin, the Beagle Sub-basin is inadequately defined and mapped. The sub-basin is a transitional area between the northern Carnarvon Basin and the Offshore Canning Basin, and contains trends that are common to both of these basins (Crostella & Barter, 1980). In the west, the two principal elements are the ENE-trending Cossigny and Beagle Troughs and the

NNE-trending fault blocks of the Beagle Platform (Blevin et al., 1994), which are analogous to the Lewis Trough and Rankin Platform, respectively. In the eastern half of the sub-basin, the dominant trend becomes N-S, as represented by the Thouin Graben and North Turtle Hinge.

TECTONIC FRAMEWORK

The evolution of the northern Carnarvon Basin was influenced by a series of tectonic events that controlled both the shape of the basin and the geometry and distribution of the basin fill. The basin's history can be subdivided into phases that are defined by these events (AGSO North West Shelf Study Group, 1994):

1) Late Devonian - Initiation of a major phase of intra-continental, upper-crustal extension that continued into the Early Carboniferous - In the northern Carnarvon, this event is expressed by growth on faults on the Candace Terrace.

2) Middle Carboniferous - Extension and the initiation of the Westralian Superbasin (Yeates & others, 1987) - Crustal extension primarily along NE-trending normal faults separated by NW-trending transfer faults. These faults have probably determined the structural grain of the North West Shelf for the remainder of its history. The Scholl Island Fault is an example of an extensional fault of this age (e.g. see figures 5 & 7 in Bentley, 1988).

3) Late Permian - Bedout Movement - A regional structuring event that gave rise to a varied set of structural styles in various parts of the northern Carnarvon. Extensional, transtensional and transpressional features are all observed.

4) Late Triassic - Fitzroy Movement - Late Triassic to Early Jurassic faulting is widespread, particularly on the Rankin Trend and the Exmouth Plateau. This faulting has traditionally been interpreted as extensional and has been referred to frequently as 'rift onset'; however, the steep dips on these faults, the non-systematic fault block rotations on the Rankin Trend, and fault discontinuity indicate strike-slip faulting, interpreted to be in a left-lateral sense. This was the period of initiation of the major Jurassic depocentres of the northern Carnarvon, the Exmouth, Barrow, Dampier and Beagle Sub-basins. Rapid subsidence regionally led to the deposition of source rocks in many basins and sub-basin depocentres on the North West Shelf at this time, including the northern Carnarvon. Structures formed at this time serve as traps for most of the large gas fields of the North West Shelf (North Rankin, Goodwyn, West Tryal Rocks, Gorgon).

5) Mid - Late Jurassic (Callovian - Oxfordian) - Argo Breakup - This event is associated with the initiation of sea-floor spreading in the Argo Abyssal Plain and is expressed in the northern Carnarvon Basin by minor compression and erosion. The formation of a regional unconformity referred to as the 'Main Unconformity' (MU) occurred at this time.

6) Early Cretaceous (Valanginian) - Cuvier-Gascoyne Breakup - Sea-floor spreading in the Gascoyne and Cuvier Abyssal plains began at this time. Compression and erosion occurred in the Exmouth Sub-basin, but elsewhere the effects of this tectonic event are indistinct.

7) Mid-Cretaceous (Cenomanian) - Middle to Late Cretaceous faulting is largely restricted to NE-trending high-angle zones that are complexly structured. This phase of faulting has formed many of the structures on the oil-rich trend from Saladin to Talisman. Fault geometries again indicate dominantly left-lateral wrench motion.

8) Miocene - Collision along the northern margin of Australia commenced in the Mid-Oligocene, but the effects of that event began to be manifest along the southern half of the North West Shelf in the Miocene. A final episode of wrench movement and fault reactivation occurred in response to the collision of Australia with Timor. This activity is still evident today, particularly in the Timor Sea, where some faults reach seabed. Intraplate stresses within the Australia-India plate had some influence on fault reactivation in the Late Miocene. In both the Timor Sea basins and in the northern Carnarvon Basin, these tectonic events are thought to be responsible for initiating periods of fault reactivation with associated hydrocarbon leakage and migration that resulted in residual oil columns in several fields.

During each phase of the basin's history, reactivation of pre-existing structures is an important consequence of the basin-forming tectonic events. The impact on timing of formation and modification of traps and fluid migration pathways is of critical importance to the petroleum exploration industry. The proposed high-resolution survey will provide the quality and resolution necessary to investigate this problem.

STRATIGRAPHY

A summary of general stratigraphy is provided in Figure 10. The North West Shelf is well-explored by Australian standards, and the stratigraphy is relatively well-documented, particularly in the Barrow and Dampier Sub-basins. This following section is based upon the studies of Parry & Smith (1988) and Woodside (1988).

PALAEOZOIC

Because of the great thickness of Mesozoic sediments beneath much of the northern Carnarvon Basin, Palaeozoic sediments have only been sampled infrequently. Carboniferous and Devonian rocks have been penetrated in Rough Range-1 and at shallower depth in wells on the Peedamullah Shelf, between the Flinders Fault System and the Scholl Island Fault. The Permian Byro Group has been documented in several wells on the Peedamullah Shelf and to the south, where it includes dark shale and siltstone with some sandstone. Parry & Smith (1988) believe that this sequence deserves more attention, given that there is a distinct possibility that shales in the group have generated hydrocarbons at some time and the fact that good-quality reservoir sandstones are present in the overlying Upper Permian Chinty Formation.

MESOZOIC-CAINOZOIC

Mesozoic sedimentation commenced with the deposition of the Scythian to Ladinian Locker Shale. This sequence consists of a basal transgressive coarse paralic sandstone and a thin shelfal limestone overlain by sandy shales. The bulk of this sequence consists of a thick marine section of interbedded claystone and minor siltstone with a thin regressive sandy sequence at the top.

The Locker Shale grades upwards into the Late Triassic Mungaroo Formation, a dominantly fluvial sandstone sequence, with some coals. This sequence is the principal reservoir for the major gas accumulations of the Rankin Trend. The coarse clastics in the sequence were probably deposited in a braided channel or fluvio-estuarine environment, whereas the interbedded claystones and coals represent flood-plain deposits with minor marine influences. At the top of the Mungaroo Formation there appears to be a return to a more marine environment, and there are widespread Rhaetian shelf carbonates along the northern margin of the Exmouth Plateau (von Rad, Haq, et al., 1992).

Overlying the Mungaroo Formation across most of the Dampier Sub-basin is a widespread Hettangian-Sinemurian sandstone sequence (North Rankin Beds; Woodside, 1988). These consist of marginal marine and fluvial sandstones interbedded with minor marginal marine and estuarine claystone, and was deposited in a nearshore/shoreline environment.

During most of the Jurassic, the thick Dingo Claystone was deposited across the southern North West Shelf. This formation is divided by Woodside (1988) into three sub-units - the lower, middle, and upper Dingo Claystone. Lateral equivalents include the more coarse- grained siliciclastic Biggada, Dupuy, Legendre, and Angel Formations. The base of the lower Dingo Claystone is marked by a transgression and an abrupt lithologic change from clastics to carbonates; this generated a basin-wide seismic marker. With deepening of the basin, the carbonates were succeeded by inner shelf calcareous claystones. In the Bajocian-Bathonian, a regional regression led to the deposition of westwards-prograding deltaic sediments across the northern Barrow-Dampier Sub-basins. This regression reached its maximum extent towards the end of the Middle Jurassic, coincident with a major phase of tectonic movement. This led to the formation of the ubiquitous 'Main Unconformity' (MU), separating the middle and upper Dingo Claystones, which has historically been interpreted as the expression of final continental breakup in the Argo Abyssal Plain. Much of the southern North West Shelf was emergent at this time; marine conditions persisted only in the rapidly-subsiding areas of the Lewis Trough and the Madeleine Trend.

The remainder of the Jurassic was characterized by sedimentation in a true divergent margin setting with predominantly fine-grained mixed clastic sediments (upper Dingo Claystone) being rapidly deposited in the Lewis Trough. Within the uppermost part of the Dingo Claystone, a marine sandstone unit (Dupuy Sandstone Member) was deposited in moderate to deep water in the vicinity of Barrow Island and possibly also around the edges of the Rankin Platform.

The Dingo Claystone is disconformably overlain by the Barrow Group, a generally northwards-prograding regressive sequence of clastics of mainly Neocomian age. Three units have been named within the Barrow Group - the Malouet and Flacourt Formations, respectively comprising the bottomsets and foresets/topsets of the delta, and the Flag Sandstone (Kopsen & McGann, 1985), a massive submarine fan sandstone that is a facies equivalent of the Malouet Formation. The relationship between these three formations is shown diagrammatically in Howell (1988, figure 8) and Barber (1988, figure 7).

A major transgression beginning in the late Valanginian initiated the deposition of the units of the Winning Group (successively, the Birdrong Sandstone, Muderong Shale, Windalia Sandstone Member, Windalia Radiolarite, Gearle Siltstone and Haycock Marl). It is likely that this transgression was in response to margin breakup adjacent to the Perth Basin. The basal transgressive unit consists of the Birdrong Sandstone along much of the Peedamullah Shelf, and the mid- and outer-shelf Mardie Greensand to the south of Barrow island. Both units consist of quartzose sandstone; the Birdrong also contains minor interbedded siltstone, while the Mardie Greensand is heavily glauconitic. The basal sands were succeeded by the Muderong Shale, a widespread unit of marine claystones which provides a regional seal for most of the hydrocarbon accumulations in the Barrow and Dampier Sub- basins. A minor regressive phase is indicated by the deposition of the Windalia sandstone Member, a storm-winnowed shelf sand, at the top of the Muderong Shale.

In the Aptian, a marked environmental change and a rise in sea level led to the deposition of the widespread Windalia Radiolarite, composed of radiolarite grading basinwards to radiolarian claystone, siltstone, and chert. The Windalia Radiolarite was succeeded by the Gearle Siltstone in the Barrow area and the Haycock Marl in the Dampier Sub-basin, with these units being deposited in open ocean settings.

Extensive carbonate sedimentation commenced in the Turonian with the deposition of the Toolonga Calcilutite. During the remainder of the Cretaceous, sedimentation was fairly evenly split between open marine carbonates and claystones (Korojon Calcarenite, Withnell Formation, and Miria Marl). Most of the Tertiary sequences on the North West Shelf are the result of out- and up-building of the continental shelf during a series of transgressive/regressive sea-level pulses, with the dominant sediment type being carbonate (Cardabia Group, Giralia Calcarenite, Cape Range Group).

HYDROCARBON ACCUMULATIONS

The hydrocarbon fields of the northern Carnarvon Basin fall into two categories (Vincent & Tilbury, 1988) - those reservoired in the pre-'Main Unconformity' (pre-MU) section (Argo Breakup, Fig. 10), and those reservoired in the post-MU section (Appendix 9).

The pre-MU fields are characterised by the fault blocks of the southeastern edge of the Rankin Platform (Rankin Trend), which host several giant gas/condensate fields - most notably North Rankin, Goodwyn, and Gorgon. These fields are sub-unconformity traps and have in common reservoirs of the fluviatile Mungaroo Formation and are sealed by the Cretaceous Muderong Shale (much of the intervening Jurassic-Cretaceous section is absent through non-deposition or erosion). Sourcing is interpreted to be from the immense thickness of lower Dingo Claystone in the Lewis Trough, and possibly also from the Triassic (Pre-Mungaroo Formation) Locker Shale. The fault blocks are frequently tilted or triangular in outline, with varying degrees of rotation and, as discussed previously, appear to be wrench reactivations of older structures.

The post-MU hydrocarbon fields are generally much more subtle than the Rankin Trend fault blocks and they tend to be oil-prone. With some exceptions (Barrow Island and, more recently, Wanaea-Cossack) the field sizes have tended to be quite small. There is a greater variety of traps than with the pre-MU fields, with trap types including drape, anticlines (some faulted), rollover into faults, and fault-controlled (Appendix 9). As with the pre-MU fields, most, if not all of these fields are the result of reactivation of older structures. Hydrocarbons are primarily reservoired in three sections - Jurassic Angel Formation, Cretaceous Barrow Group (including Flag Sandstone), and

Cretaceous Winning Group (particularly Windalia Sandstone Member and Mardie Greensand). In general, the Jurassic reservoirs are gas-rich and found on the Rankin Trend and in adjacent structures, while the Cretaceous reservoirs are oil-rich and found within the basins (eg Barrow Island) or along the southeast basin flank. As with the pre-MU fields, sourcing is probably from the Dingo Claystone.

In the literature, until recently, there has typically been reference to an 'inner oil trend' and an 'outer gas trend'. Until the late 1980's this was generally true, with hydrocarbon discoveries on the outer flank of the rift (Rankin Trend) being predominantly gas/condensate, while oil was the principal discovery within the rift or on the inner flank. However, with the successes at Chinook/Griffin/Ramillies and Wanaea/Cossack, on the Alpha Arch and the Madeleine Trend, the distinction between oil and gas trends is breaking down.

APPENDIX 3

R/V RIG SEISMIC

R/V Rig Seismic is a seismic research vessel with dynamic positioning capability, chartered and equipped by the Australian Geological Survey Organization to carry out the Continental Margins Program. It was built in Norway in 1982 and fitted out in Australia for geoscientific research in October 1984.

Name:	R/V Rig Seismic
Owner:	Galerace Ltd.
Registration:	Research Vessel
Home Port:	Newcastle, New South Wales
Length:	72.5 metres
Beam:	13.8 metres
Draft:	6.0 metres
Gross tonnage:	1595 tonnes
Net tonnage:	421 tonnes
Displacement:	3000 tonnes
Main engines:	Bergen Type Norma KVMB-12; 2640HP/825rpm
Auxiliary engines:	3 Caterpillar; 564HP/482KVA 1 Mercedes; 78HP/ 56KVA 1 GEC dynamic positioning system
Shaft generator:	AVK 1000KVA; 440V/60Hz
Side thrusters:	2 forward, 1 aft, each 600HP
Cruising speed:	10 knots
Maximum speed:	13 knots
Propellers:	1 variable pitch
Gyro compass:	Sperry Mk 37
Fuel capacity:	483.55 tonnes
Endurance:	20000 at 13 knots 13,500 at 5 knots

APPENDIX 4

SHIPBOARD PARTY

Seismic Crew

Glen Cassim	Vessel Manager
Maria de Deuge	QC
Leo Kalinisan	QC
Jim Bedford	TO
Dave Pryce	TO
Paul Hyde	TO
Scott Laidlaw	TO
Rob Parums	Acting TO
Steve Wiggins	Gun Mechanic
David Sewter	Gun Mechanic
Andrew Hislop	Gun Mechanic
Richard Schuler	Gun Mechanic
Ken Elphic	Gun Mechanic
Joe Mangion	Electronics Tech
Wojciech Wierzbicki	Electronics Tech

Marine Crew

Bob Hardinge	Master
Bill Orgill	Mate
Otto Weysenfeld	2nd Mate
Doug Robinson	Chief Engineer
Russ Heaton	2nd Engineer
Bob Dickman	Electrician
Bruce Noble	C.I.R.
Nicholas Clarke	I.R.
Dave Kane	I.R.
Lindsay Adcock	I.R.
Geoff Conley	Chief Cook
Alex King	Cook
Clive Blackman	Catering Attendant
Doug Graham	Catering Attendant
Lyn Carter	Supernumary (left ship by helicopter on 26th October 1994)

APPENDIX 5

WAY POINTS CARNARVON HIGH RESOLUTION SURVEY

LINE NO.	SHOT POINT	LATITUDE	LONGITUDE	TIE POINTS
136/01				
136/01	100	21 00.705	113 34.840	SOL
136/01	710	21 06.458	113 37.295	ZEEWULF 1
136/01	1896	21 17.852	113 41.482	RESOLUTION 1
136/01	4705	21 42.998	113 55.908	EOL
136/02				
136/02	100	21 44.732	114 17.123	SOL
136/02	1059	21 35.562	114 13.595	WEST MUIRON 2
136/02	1083	21 35.333	114 13.503	
136/02	1198	21 34.442	114 12.205	WEST MUIRON 3 **
136/02	1389	21 33.305	114 10.703	WEST MUIRON 4 **
136/02	2691	21 21.362	114 04.578	NOVARA 1
136/02	6406	20 48.812	113 44.212	EOL
136/03				
136/03	100	20 32.492	113 59.213	SOL
136/03	6479	21 31.782	114 27.110	OUTTRIM 1
136/03	7525	21 41.488	114 31.740	HAWKSBILL 1
136/03	7620	21 42.372	114 32.157	EOL
136/04				
136/04	1	21 29.042	114 39.425	SOL
136/04	100	21 29.832	114 40.088	SOMMERVILLE 1
136/04	477	21 32.850	114 42.610	ANCHOR 1
136/04	572	21 33.608	114 43.247	
136/0401	1030	21 30.525	114 40.277	
136/0401	1100	21 29.838	114 40.083	SOMMERVILLE 1
136/0401	2280	21 18.213	114 36.945	
136/0402	3193	21 19.073	114 37.162	
136/0402	3563	21 15.432	114 36.167	RAMILLIES 1
136/0402	6797	20 44.153	114 25.442	ZEEPAARD 1
136/0402	9862	20 14.533	114 15.227	EOL
136/05				
136/05	100	20 10.092	114 28.173	SOL
136/05	4219	20 49.423	114 43.372	MINDEN 1
136/05	6591	21 12.093	114 52.077	ROSILY 1A
136/05	7690	21 22.800	114 55.467	EOL

136/06

136/06	100	21 12.253	115 00.947	SOL
136/06	2220	20 51.103	114 56.592	KURRAJONG 1
136/06	3664	20 36.783	114 53.183	SPAR 1
136/06	5027	20 23.088	114 50.777	NORTH GORGON 1**
136/06	6027	20 13.327	114 48.465	
136/06	6030	20 13.298	114 48.455	
136/06	6940	20 14.170	114 48.748	
136/06	7028	20 13.317	114 48.465	
136/06	8447	19 59.595	114 43.772	EOL

136/07

136/07	100	19 52.635	114 55.762	SOL
136/07	1866	20 09.220	115 03.018	WEST TRYAL ROCKS 3
136/07	2236	20 12.862	115 04.003	WEST TRYAL ROCKS 2
136/07	3500	20 24.717	115 09.248	TRYAL ROCKS 1
136/07	4387	20 33.647	115 10.533	MAITLAND 1
136/07	7495	21 05.167	115 12.648	WEST PEPPER 1
136/07	8828	21 18.650	115 14.003	EOL

136/08

136/08	80	20 37.602	115 24.200	SOL
136/08	3726	20 02.563	115 11.432	SULTAN 1
136/08	5462	19 46.762	115 03.143	EOL

136/09

136/09	100	19 39.165	115 14.123	SOL
136/09	3889	20 13.605	115 32.332	FORREST 1A
136/09	5413	20 27.830	115 38.825	FLAG 1
136/09	5604	20 29.618	115 39.625	
136/09	10462	20 28.267	115 39.392	
136/09	11136	20 34.818	115 37.277	
136/09	11200	20 35.288	115 37.305	
136/09	11250	20 35.793	115 37.380	
136/09	11285	20 36.130	115 37.507	HARRIET 1**
136/09	11300	20 36.277	115 37.555	
136/09	11350	20 36.772	115 37.673	
136/09	11400	20 37.267	115 37.793	
136/09	11450	20 37.780	115 37.842	
136/09	11500	20 38.322	115 37.750	
136/09	11550	20 38.865	115 37.657	
136/09	11600	20 39.380	115 37.692	
136/09	11628	20 39.660	115 37.748	
136/09	11630	20 39.680	115 37.752	
136/09	12341	20 46.708	115 39.532	
136/09	12437	20 47.655	115 39.777	EOL

136/10

136/10	100	19 30.543	115 26.717	SOL
136/10	2483	19 47.847	115 44.602	RANKIN 1
136/10	2874	19 50.913	115 47.272	DIXON 1
136/10	5685	20 13.123	116 06.280	MAWBY 1A**
136/10	5700	20 13.242	116 06.400	
136/10	5750	20 13.485	116 06.873	
136/10	5800	20 13.658	116 07.382	
136/10	5850	20 13.840	116 07.887	
136/10	6500	20 16.527	116 14.282	
136/10	6550	20 16.747	116 14.767	
136/10	6600	20 16.997	116 15.237	
136/10	6630	20 17.147	116 15.520	STAG 1**
136/10	6838	20 18.140	116 17.500	EOL

136/11

136/11	100	20 15.028	116 35.370	SOL
136/11	1255	20 09.343	116 24.492	ENDERBY 1
136/11	2021	20 05.265	116 17.473	MONTEBELLO 1
136/11	4024	19 52.272	116 00.900	DAMPIER 1
136/11	5132	19 44.067	115 52.753	GOODWYN 3
136/11	5288	19 43.315	115 51.277	GOODWYN 6
136/11	7847	19 24.538	115 32.293	EOL

136/12

136/12	100	19 14.650	115 47.367	SOL
136/12	354	19 16.433	115 49.332	GANDARA 1
136/12	2755	19 32.677	116 08.522	NORTH RANKIN 6
136/12	2938	19 34.233	116 09.595	NORTH RANKIN 5
136/12	2995	19 34.667	116 09.998	MILLER 1
136/12	4401	19 44.002	116 21.417	
136/12	5314	19 43.422	116 20.710	
136/12	6654	19 52.322	116 31.600	ORION 1
136/12	8113	20 01.978	116 43.498	EOL

136/13

136/13	100	20 04.113	116 52.242	SOL
136/13	267	20 03.565	116 50.493	KANJI 1**
136/13	2257	19 47.527	116 37.438	LEWIS 1A
136/13	2641	19 45.842	116 34.420	BALEENA 1
136/13	3999	19 35.215	116 24.693	WANAEA 5
136/13	4406	19 31.608	116 22.558	MONTAGUE 1
136/13	7656	19 07.615	115 58.643	EOL

136/14

136/14	100	18 57.998	116 15.018	SOL

136/14	1245	19 07.183	116 22.532	
136/14	2246	19 07.193	116 22.535	
136/14	4826	19 27.892	116 39.487	ANGEL 2
136/14	6017	19 35.688	116 49.253	FORESTIER 1
136/14	6866	19 42.653	116 54.625	CYGNUS 1
136/14	7437	19 47.400	116 58.152	EOL
136/15				
136/15	110	19 49.643	117 17.257	SOL
136/15	371	19 47.575	117 15.335	HAUY 1
136/15	2861	19 29.647	116 56.488	TALISMAN 1
136/15	4421	19 17.322	116 45.980	FINUCANE 1
136/15	7356	18 54.158	116 26.208	EOL
136/16				
136/16	100	18 49.717	116 37.350	SOL
136/16	3006	19 13.972	116 55.065	SABLE 1
136/16	3852	19 20.658	117 00.758	AURORA 1
136/16	4795	19 29.258	117 05.213	DE GREY 1
136/16	5415	19 34.878	117 08.220	EOL
136/17				
136/17	100	18 39.533	117 00.550	SOL
136/17	3824	19 12.125	117 20.770	
136/17	7907	19 44.482	117 48.160	EOL
136/18				
136/18	100	19 02.555	118 15.385	SOL
136/18	2341	18 50.032	117 55.393	DEPUCH 1
136/18	2962	18 46.765	117 49.722	NEBO 1
136/18	6252	18 28.687	117 20.215	EOL
136/19				
136/19	100	18 38.852	118 04.108	SOL
136/19	1657	18 46.762	117 49.725	NEBO 1
136/19	1747	18 47.222	117 48.895	
136/19	5966	19 08.428	117 09.725	RONSARD 1
136/19	6056	19 08.880	117 08.888	
136/19	7441	19 13.978	116 55.068	SABLE 1
136/19	7529	19 14.312	116 54.195	
136/19	8352	19 17.325	116 45.978	FINUCANE 1
136/19	8438	19 17.630	116 45.117	
136/19	9055	19 17.282	116 38.452	BOUNTY 1
136/19	9144	19 17.283	116 37.498	
136/1901	100	19 17.285	116 38.455	
136/1901	2508	19 30.412	116 16.697	EAGLEHAWK 1
136/1901	2598	19 30.903	116 15.873	

136/1901	3259	19 34.668	116 10.005	MILLER 1
136/1901	3413	19 35.542	116 08.635	
136/1901	3450	19 35.733	116 08.277	
136/1901	3500	19 35.922	116 07.777	
136/1901	3512	19 35.830	116 07.577	NORTH RANKIN 1
136/1901	3550	19 36.107	116 07.225	
136/1901	4454	19 37.625	115 57.660	GOODWYN 7
136/1901	4743	19 38.628	115 54.747	GOODWYN 8
136/1901	5027	19 39.802	115 51.963	GOODWYN 2
136/1901	5115	19 40.167	115 51.103	
136/1901	5871	19 42.635	115 43.417	ECHO 1
136/1901	6952	19 45.178	115 32.130	MALUS 1
136/1901	7042	19 45.388	115 31.192	
136/1901	8786	19 59.250	115 19.218	NORTH TRYAL ROCKS 1
136/1901	8788	19 59.265	115 19.203	
136/1902	107	19 59.335	115 19.117	
136/1902	888	20 02.555	115 11.443	SULTAN 1
136/1902	1909	20 09.217	115 03.023	WEST TRYAL ROCKS 3
136/1902	2727	20 15.415	114 57.155	BLUEBELL 1
136/1902	3624	20 23.153	114 52.042	NORTH GORGON 1**
136/1902	4202	20 28.062	114 48.640	CENTRAL GORGON 1
136/1902	6872	20 44.153	114 25.442	ZEEPAARD 1
136/1902	12128	21 17.925	113 41.380	RESOLUTION 1
136/1902	12814	21 22.373	113 35.652	EOL

136/20

136/20	9076	20 12.967	115 33.155	SOL
136/20	9175	20 13.610	115 32.333	FORREST 1A
136/20	12001	20 33.658	115 10.528	MAITLAND 1
136/20	13130	20 39.263	114 59.898	EAST SPAR 2**
136/20	13358	20 40.667	114 57.918	
136/20	13760	20 42.885	114 54.273	
136/2001	14673	20 42.412	114 55.067	
136/2001	14762	20 42.892	114 54.252	
136/2001	15956	20 49.422	114 43.380	MINDEN 1
136/2001	17000	20 57.022	114 35.507	YORK 1
136/2001	17031	20 57.247	114 35.270	
136/2001	19818	21 14.720	114 11.520	VLAMING HEAD 1
136/2001	20732	21 21.355	114 04.583	NOVARA 1
136/2001	23025	21 37.882	113 47.040	
136/2002	100	19 20.410	116 51.665	
136/2002	1455	19 27.892	116 39.480	ANGEL 2
136/2002	1864	19 30.258	116 35.878	ANGEL 1A
136/2002	2030	19 31.045	116 34.302	
136/2002	2501	19 32.542	116 29.427	COSSACK 1**
136/2002	2800	19 34.693	116 27.002	WANAEA 3
136/2002	2914	19 35.505	116 26.127	WANAEA 2

136/2002	3091	19 36.742	116 24.748	
136/2002	3455	19 38.908	116 21.585	MADELEINE 1
136/2002	5787	19 52.262	116 00.905	DAMPIER 1
136/2002	7246	20 01.113	115 48.325	WITHNELL 1
136/2002	9163	20 13.530	115 32.430	FORREST 1A
136/21				
136/21	169	21 32.068	114 26.973	SOL
136/21	199	21 31.802	114 27.130	OUTTRIM 1
136/21	2003	21 15.647	114 36.377	
136/21	2916	21 16.437	114 35.923	
136/21	3180	21 14.072	114 37.277	GRIFFIN 1
136/21	3412	21 11.915	114 38.290	HILDA 1A
136/21	3834	21 07.955	114 40.043	EOL
136/22				
136/22	100	21 25.540	114 37.618	SOL
136/22	1979	21 12.100	114 52.088	ROSILY 1A
136/22	5399	20 47.432	115 18.152	EOL
136/23				
136/23	100	20 11.865	115 14.800	SOL
136/23	624	20 08.447	115 19.123	VENTURE 1
136/23	1840	20 00.453	115 29.098	WILCOX 1
136/23	1992	19 59.665	115 30.503	WILCOX 2
136/23	2050	19 59.273	115 30.967	
136/23	2091	19 58.975	115 31.275	
136/23	2965	19 52.808	115 38.037	
136/23	3512	19 49.333	115 42.620	FISHER 1
136/23	3747	19 47.855	115 44.603	RANKIN 1
136/23	3968	19 47.200	115 46.872	DOCKRELL 1
136/23	4444	19 45.952	115 51.808	PUEBLO 1
136/23	4571	19 46.040	115 53.170	TIDEPOLE 1
136/23	5029	19 46.100	115 58.085	EOL
136/24				
136/24	100	20 27.825	115 38.808	FLAG 1
136/24	250	20 27.017	115 40.180	
136/24	517	20 25.565	115 42.612	
136/24	550	20 25.330	115 42.875	
136/24	600	20 24.950	115 43.258	
136/24	649	20 24.558	115 43.620	CAMPBELL 2
136/24	660	20 24.462	115 43.723	
136/24	700	20 24.228	115 44.078	
136/24	750	20 24.055	115 44.593	
136/24	800	20 23.980	115 45.165	
136/24	835	20 23.913	115 45.557	

136/24	3032	20 13.127	116 06.277	MAWBY 1A**
136/24	5099	19 57.193	116 20.765	ROSEMARY 1
136/24	5543	19 54.652	116 24.707	ROSEMARY NORTH 1
136/24	6740	19 46.763	116 34.492	BALEENA 1
136/24	7232	19 43.567	116 38.553	SAMSON 1
136/24	7836	19 40.242	116 44.002	LEGENDRE 1
136/24	8226	19 37.378	116 46.895	LEGENDRE 2
136/24	8502	19 35.683	116 49.252	FORESTIER 1
136/24	8787	19 33.533	116 51.298	NELSON ROCKS 1
136/24	9305	19 30.275	116 55.662	TALISMAN 2
136/24	9403	19 29.645	116 56.475	TALISMAN 1
136/24	9617	19 28.163	116 58.153	ALPHA NORTH 1
136/24	11603	19 19.808	117 17.515	COSSIGNY 1
136/24	16724	18 54.505	118 05.365	NORTH TURTLE 1
136/24	16911	18 53.563	118 07.098	EOL
136/25				
136/25	80	21 17.588	113 41.535	SOL
136/25	100	21 17.857	113 41.477	RESOLUTION 1
136/25	3581	22 04.380	113 33.228	
136/25	4517	22 03.522	113 33.378	
136/25	4582	22 04.392	113 33.225	
136/25	10012	23 16.950	113 20.243	PENDOCK 1
136/25	10086	23 17.937	113 20.073	EOL
136/26				
136/26	100	21 39.998	113 30.000	SOL
136/26	1794	21 43.880	113 54.200	EOL
136/27				
136/27	100	21 53.595	113 47.402	SOL
136/27	1538	21 50.858	113 26.742	EOL
136/28				
136/28	100	22 00.305	113 25.497	SOL
136/28	1362	22 02.893	113 43.622	EOL

**These wells tie off-line.

APPENDIX 6

WELLS TIED

WELLNAME	OPERATOR	DATE	TD	AGE AT TD
ALPHA NORTH 1	MARATHON	7/89	2200	M. JURASSIC
ANCHOR 1	WAPET	8/69	3049	
ANGEL 1A	BURMAH OIL	11/72	3411	U. JURASSIC
ANGEL 2	BURMAH OIL	5/72	4397	L. JURASSIC
AURORA 1	MARATHON	12/90	3020	
BALEENA 1	PHILLIPS	6/93		
BLUEBELL 1	WAPET	4/83	4605	U. TRIASSIC
BOUNTY 1	MARATHON	7/83	3524	U. JURASSIC
CAMPBELL 2	BOND CORP	3/86	2796	CRETACEOUS
CENT. GORGON 1	WAPET	7/83	4598	
CHERVIL 3	WESMINCO	5/85	1350	E. CRETACEOUS
COSSACK 1	WOODSIDE	1/90	3030	JURASSIC
COSSIGNY 1	WOODSIDE	11/72	3203	M. TRIASSIC
CYGNUS 1	ARCO AUST	8/89	2470	
DAMPIER 1	BURMAH OIL	5/69	4143	U. JURASSIC
DE GREY 1	BURMAH OIL	10/71	2088	TRIASSIC
DEPUCH 1	WOODSIDE	3/74	4300	L. JURASSIC
DIXON 1	WOODSIDE	5/84	4357	U. TRIASSIC
DOCKRELL 1	WOODSIDE	3/73	3895	U. TRIASSIC
EAGLEHAWK 1	WOODSIDE	12/72	3490	U. TRIASSIC
EAST SPAR 2	WMC	9/93		
ECHO 1	WOODSIDE	10/88	3775	TRIASSIC
ENDERBY 1	BURMAH OIL	10/70	2149	?PERMIAN
FINUCANE 1	WOODSIDE	11/78	3300	M. JURASSIC
FISHER 1	WOODSIDE	8/81	3762	U. TRIASSIC
FLAG 1	WAPET	1/70	3800	JURASSIC
FORESTIER 1	WOODSIDE	9/86	2514	U. JURASSIC
FORREST 1A	PHILLIPS	10/92	3426	U. JURASSIC
GANDARA 1	HUDBAY	7/79	4361	U. TRIASSIC
GEORGETTE 1	OCCIDENTAL	9/83	2392	M. JURASSIC
GOODWYN 2	BURMAH OIL	5/72	3750	M. TRIASSIC
GOODWYN 3	WOODSIDE	2/73	3658	U. TRIASSIC
GOODWYN 6	WOODSIDE	12/81	4664	U. TRIASSIC
GOODWYN 7	WOODSIDE	9/85	3445	U. TRIASSIC
GOODWYN 8	WOODSIDE	5/86	3197	U. TRIASSIC
GRIFFIN 1	BHP	2/90	3400	
HAUY 1	WOODSIDE	12/72	825	
HAWKSBILL 1	HADSON	12/93		
HILDA 1A	WAPET	9/74	3466	U. TRIASSIC
KURRAJONG	AMPOLEX	12/93		
LEGENDRE 1	BURMAH OIL	6/68	3473	M. JURASSIC
LEGENDRE 2	BURMAH OIL	12/70	3618	L. JURASSIC
LEWIS 1A	BURMAH OIL	2/76	3400	M. JURASSIC
LOWENDAL 1	WOODSIDE	3/74		
MADELEINE 1	BURMAH OIL	12/69	4429	JURASSIC
MAITLAND 1	WMC	9/92	1502	JURASSIC
MALUS 1	WOODSIDE	11/72	3658	U. TRIASSIC

WELLNAME	OPERATOR	DATE	TD	AGE AT TD
MILLER 1	WOODSIDE	5/78	3520	U. TRIASSIC
MINDEN 1	BHP	5/91	4022	L. CRETACEOUS
MONTEBELLO 1	BHP	12/89	2750	M. JURASSIC
NEBO 1	KUFPEC	4/93	3132	M. JURASSIC
NELSON ROCKS 1	WOODSIDE	7/73	2190	U. JURASSIC
N. RANKIN 1	BURMAH OIL	6/71	3534	M. TRIASSIC
N. RANKIN 5	WOODSIDE	2/77	3500	U. TRIASSIC
N. RANKIN 6	WOODSIDE	4/81	3900	U. TRIASSIC
N. TRYAL RCKS 1	WAPET	7/72	3658	
N. TURTLE 1	BP	9/82	4420	U. TRIASSIC (?)
NOVARA 1	ESSO EX	10/82	2753	L. CRETACEOUS
ORION 1	WOODSIDE	8/90	2500	M. JURASSIC
OUTTRIM 1	ESSO EX	7/84	1725	U. JURASSIC
PUEBLO 1	WOODSIDE	4/79	3485	U. TRIASSIC
RAMILLIES 1	BHP	12/90	3151	
RANKIN 1	BURMAH OIL	9/71	4111	TRIASSIC
RESOLUTION 1	ESSO	11/79	3883	TRIASSIC
RONSARD 1	WOODSIDE	11/73	2848	L. JURASSIC
ROSEMARY 1	WOODSIDE	3/73	3909	JURASSIC
ROSEMARY N. 1	WOODSIDE	11/82	2263	U. JURASSIC
ROSILY 1A	WAPET	5/82	3066	L. CRETACEOUS
SABLE 1	WOODSIDE	10/72	3972	U. TRIASSIC
SAMSON 1	WOODSIDE	10/84	3750	M. JURASSIC
SOMERVILLE 1	BHP	2/87	1749	L. CRETACEOUS
SPAR 1	WAPET	9/76	3721	L. CRETACEOUS
STAG 1	HADSON	6/93	933	
SULTAN 1	WAPET	3/79	3620	U. TRIASSIC
TALISMAN 1	MARATHON	8/84	2924	
TALISMAN 2	MARATHON	6/85	2326	U. JURASSIC
TIDEPOLE 1	BURMAH OIL	11/75	3491	U. TRIASSIC
TRYAL ROCKS 1	WAPET	8/70	3695	U. JURASSIC
VENTURE 1	WAPET	10/90	3324	
VLAMING HEAD	CANADA NW	9/82	2068	L. CRETACEOUS
WANAEA 1	WOODSIDE	5/89	4154	M. JURASSIC
WANAEA 2	WOODSIDE	3/90	3000	JURASSIC
WANAEA 3	WOODSIDE	7/90	2991	JURASSIC
WANAEA 5	WOODSIDE	7/92	3210	U. JURASSIC
W. MUIRON 2	WAPET	10/75	3320	
W. MUIRON 3	BHP	10/92	1200	JURASSIC
W. MUIRON 4	BHP	5/93		
W. PEPPER 1	WMC	5/91	1470	
W. TRYAL RKS 2	WAPET	11/74	3825	U. TRIASSIC
W. TRYAL RKS 3	WAPET	12/81	4035	U. TRIASSIC
WILCOX 1	WOODSIDE	2/83	4024	U. TRIASSIC
WILCOX 2	WOODSIDE	8/85	4117	U. TRIASSIC
WITHNELL 1	BURMAH OIL	6/76	4650	M. JURASSIC
YORK 1	BHP	6/93		
ZEEPAARD 1	ESSO	10/80	4215	U. TRIASSIC
ZEEWULF 1	ESSO	5/79	3500	U. TRIASSIC

APPENDIX 7

SEISMIC ACQUISITION PARAMETERS

	Main survey	Additional lines
<u>Seismic Cable Configuration</u> -	Main survey	Additional lines
Streamer length	3000m	3000m
Group length	12.5m	12.5m
No. of groups	240	240
<u>Seismic Source</u>		
Airgun capacity	19.66 l	19.66 l (1200 cu. in.)
Airgun pressure	1800 psi	1800 psi
No. of guns	8	8
Shot interval	18.75m	25m
<u>Fold</u>		
Standard	8000%	6000%
<u>Recording Parameters</u>		
Record length	5.5 sec	8.0 sec
Sample interval	2.0 msec	2.0 msec

APPENDIX 8

EQUIPMENT UTILISED

AGSO MUSIC Seismic Recording System - 240 seismic data channels per streamer; 14 auxiliary channels per streamer.

FJORD Instruments Analogue Streamer; 16 Syntron RCL-3 cable levellers; individual remote control and depth readout

Seismic Systems Inc. GI airguns, 8 x 2.46 l (150 cu. in.) airguns giving a total of 19.66 l (1200 cu. in.) operating volume

Air compressor system: 6 x A-300 Price compressors, each providing 300 scfm at 2000 psi (62 litres/min at 14 MPa)

Digital seismic acquisition system designed and built by AGSO: 16-bit floating point, SEG-Y output on cartridge tape

Raytheon echo-sounders: 3.5KHz (2 kW) 16-transducer sub-bottom profiler, and 12 KHz (2 kW) precision echo-sounder

Geometrics G801/803 magnetometer/gradiometer

Bodenseewerk Geosystem KSS-31 marine gravity meter

Racal Multifix I(primary) and II(secondary) differential GPS

Magnavox MX100 GPS receiver

Magnavox MX 610 and Raytheon DSN 450 dual axis sonar dopplers

APPENDIX 9

SURVEY 136 SEISMIC TAPE LISTING

Line No.	FSP	FCSP	LSP	LCSP	First Tape	Last Tape	Total km
01(0100)	100	100	4705	4705	136/276	136/317	86.36
02(0200)	100	100	6406	6406	136/318	136/374	118.26
03(0300)	100	100	7620	7620	136/375	136/443	141.02
04(0400)	1	1	572	572	136/462	136/467	10.73
04(0401)	1030	1030	2280	2280	136/468	136/480	23.45
04(0402)	3281	3281	9862	9862	136/492	136/552	123.42
05(0500)	100	100	7690	7690	136/553	136/621	142.33
06(0600)	100	100	6730	6027	136/622	136/682	111.15
06(0601)	6940	7028	8447	8447	136/683	136/697	26.62
07(0700)	100	100	8828	8828	136/698	136/776	163.67
08(0800)	80	80	8462	8462	136/777	136826	100.93
09(0900)	100	100	5604	5604	136/827	136/877	103.22
09(0901)	10462	10462	12437	12437	136/878	136/896	37.05
10(1000)	100	100	6838	6838	136/1109	136/1170	126.35
11(1100)	100	100	7847	7847	136/1171	136/1241	145.28
12(1200)	100	100	4458	4401	136/1242	136/1281	80.66
12(1201)	5314	5402	8113	8113	136/1282	136/1307	50.85
13(1300)	100	100	7656	7656	136/1308	136/1376	141.69
14(1400)	100	100	1370	1245	136/1377	136/1389	21.49
14(1401)	2157	2246	7437	7437	136/1390	136/1438	97.35
15(1500)	100	100	7356	7356	136/1439	136/1504	136.07
16(1600)	100	100	5415	5415	136/1505	136/1553	99.68
17(1700)	100	100	7907	7907	136/1843	136/1913	146.40
18(1800)	100	100	6252	6252	136/1787	136/1842	115.37
19(1900)	100	100	9144	9144	136/001	136/082	169.59
19(1901)	100	100	21504	21504	136/083	136/275	401.35
20(2000)	9076	9076	13760	13760	136/897	136/938	87.85
20(2001)	14673	14761	23025	23025	136/939	136/1014	154.96
20(2002)	100	100	9163	9075	136/1554	136/1635	168.30
21(2100)	169	169	2003	2003	136/444	136/461	34.40
21(2101)	3004	3004	3834	3834	136/481	136/491	15.58
22(2200)	100	100	5399	5399	136/1015	136/1063	99.38
23(2300)	100	100	5029	5029	136/1064	136/1108	92.44
24(2400)	100	250	16911	16911	136/1636	136/1786	312.41
25(2500)	80	80	3581	3581	136/1914	136/1952	87.55
25(2501)	4517	4517	10086	10086	136/2005	136/2066	137.63
26(2600)	100	100	1794	1794	136/1985	136/2004	42.37
27(2700)	100	100	1538	1538	136/1968	136/1984	35.98
28(2800)	100	100	1362	1362	136/1953	136/1967	31.57

APPENDIX 10

NORTHERN CARNARVON BASIN - OIL & GAS FIELDS
(Summarised from Cockbain, 1989)

PRE-BREAKUP FIELDS

Basin	Year	Company	Age	Trap[1]
Barrow Deep	1973	Wapet	Ju	A
Dockrell	1979	Woodside	Tr	TiFB
Eaglehawk	1972	Woodside	Tr	HB
Goodwyn	1971	Woodside	Tr, Ju	TiFB
Goodwyn South	1973	Woodside	Tr	TrFB
Gorgon	1981	Wapet	Tr	HB
Nebo*	1993	Kufpec	Ju	F-C,A
North Rankin	1971	Woodside	Tr, Ju	HB
N Rankin West	1972	Woodside	Ju	FB
Rankin	1971	Woodside	Tr	TiFB
Tidepole	1975	Woodside	Tr	TiFB
West Tryal Rocks	1973	Wapet	Tr	HB
Wilcox	1983	Woodside	Tr	FB

POST-BREAKUP FIELDS

Basin	Year	Company	Age	Trap[1]
Angel	1972	Woodside	Ju	D
Bambra	1982	Bond	Cret	A
Barrow Island	1964	Wapet	Ju, Cret	A
Campbell	1986	Bond	Cret	A
Chervil	1983	WMC	Cret	FA
Cossack*	1990	Woodside	Ju	A
Cowle*		Wapet	Cret?	F-C
Dixon	1984	Woodside	Ju	D
Egret	1973	Woodside	Ju	F-C
Harriet	1983	Bond	Cret	F-C
Lambert	1974	Woodside	Ju	R
Legendre	1968	Woodside	Cret	FA
Macedon-Pyrenees*	1992	BHP/Ampol	Cret	FA
North Herald	1983	WMC	Cret	FA
Rivoli*	1989	Minora	Cret	FA
Roller*		Wapet	Cret	A
Rosette	1987	Bond	Cret	A
Saladin	1985	Wapet	Cret	F-C
Scarborough	1979	Esso	Cret	Dome
Skate*		Wapet	Cret	A

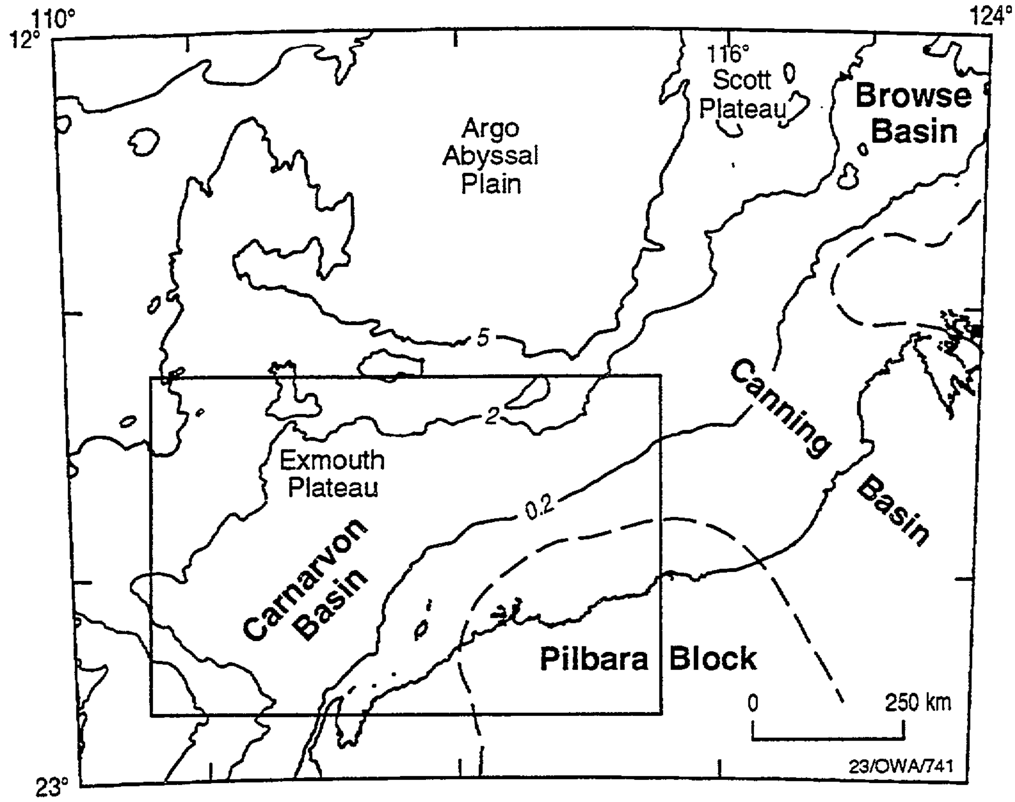
Basin	Year	Company	Age	Trap[1]
Sinbad*	1990	Hadson	Cret	F-C
South Chervil	1983	WMC	Cret	FA
South Pepper	1983	WMC	Cret	FA
Spar	1976	Wapet	Cret	R
Stag*	1993	Hadson	Cret	A
Talisman	1984	Marathon	Cret	F-C
Tanami*	1991	Hadson	Cret	A
Tubridgi	1981	Otter	Cret	A
Ulidia*	1992	Hadson	Cret	A
Wandoo*	1991	Ampolex	Cret	D
Wanaea*	1989	Woodside	Ju	A
Yammaderry*		Wapet	Cret	F-C

Notes

[1] Trap types as follows -

A	Anticline
TiFB	Tilted fault block
HB	Horst block
TrFB	Triangular fault block
FB	Fault block
D	Drape
FA	Faulted anticline
F-C	Fault-controlled
R	Rollover

* Discoveries post Cockbain, 1989



1. Location map showing the northern Carnarvon Basin and North West Shelf (from Stagg & Colwell, 1994).

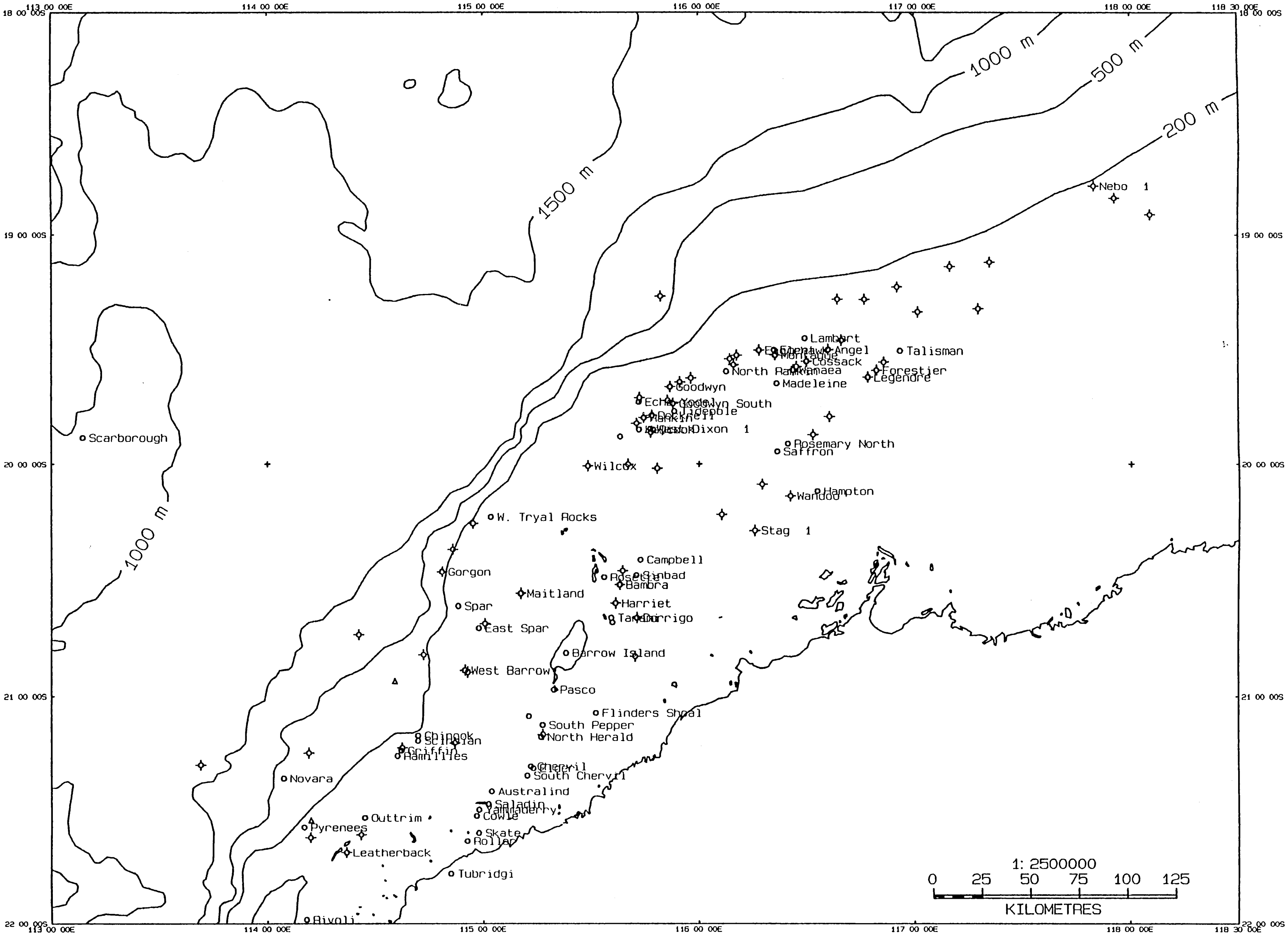


Figure 2 - Locations of hydrocarbon accumulations in the northern Carnarvon Basin

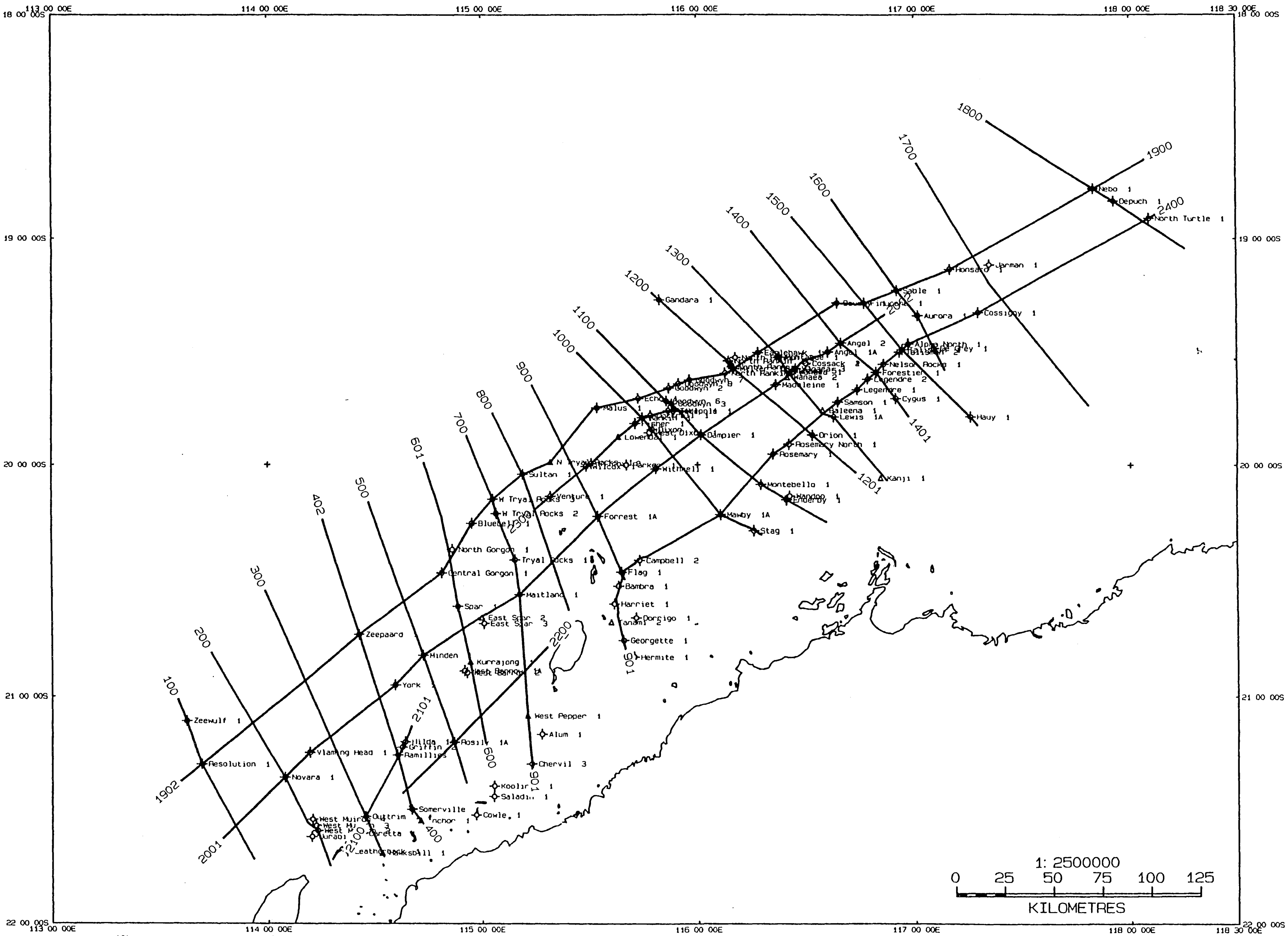


Figure 3 - Location of tie wells and seismic lines acquired during Survey 136: main survey area

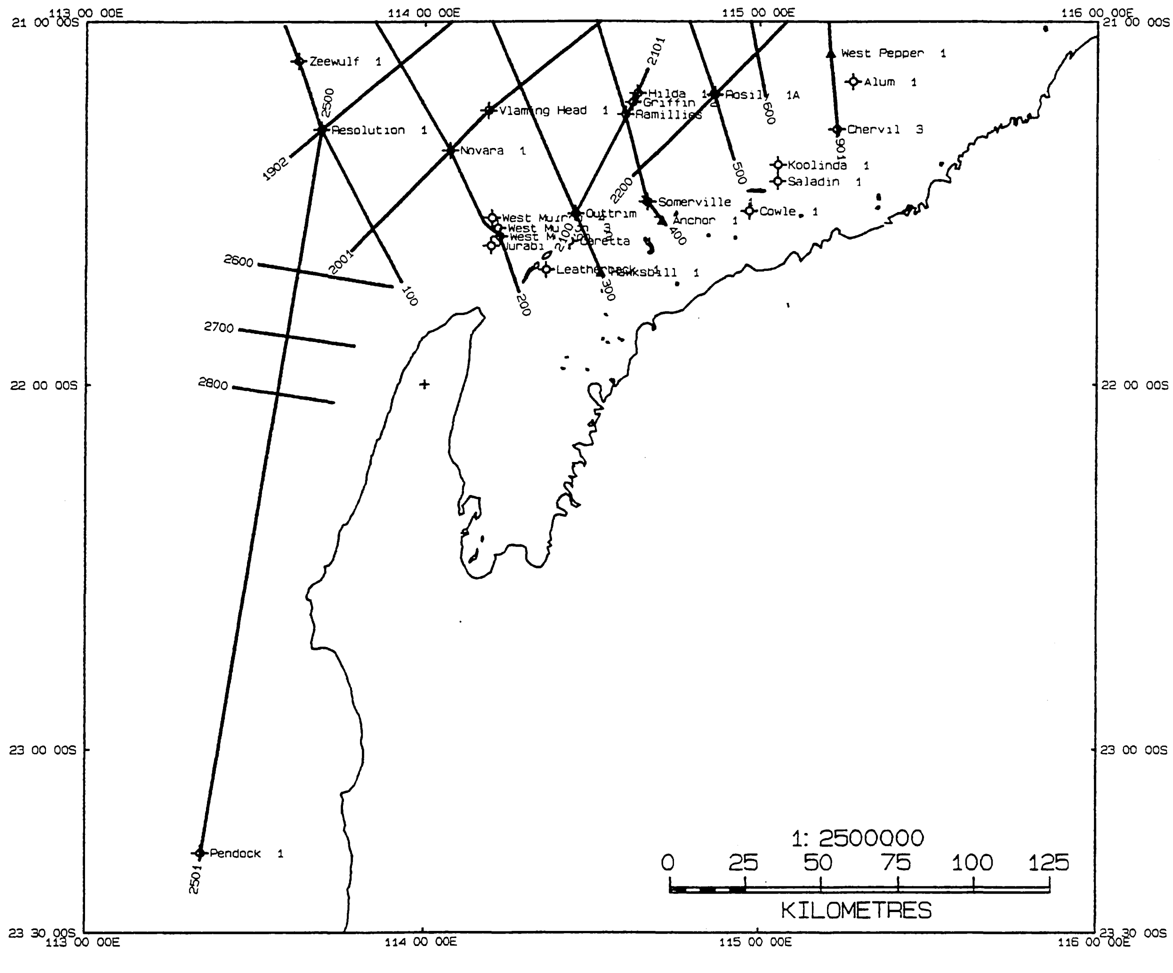


Figure 4 - Location of tie wells and additional seimic lines appended at the end of Survey 136.

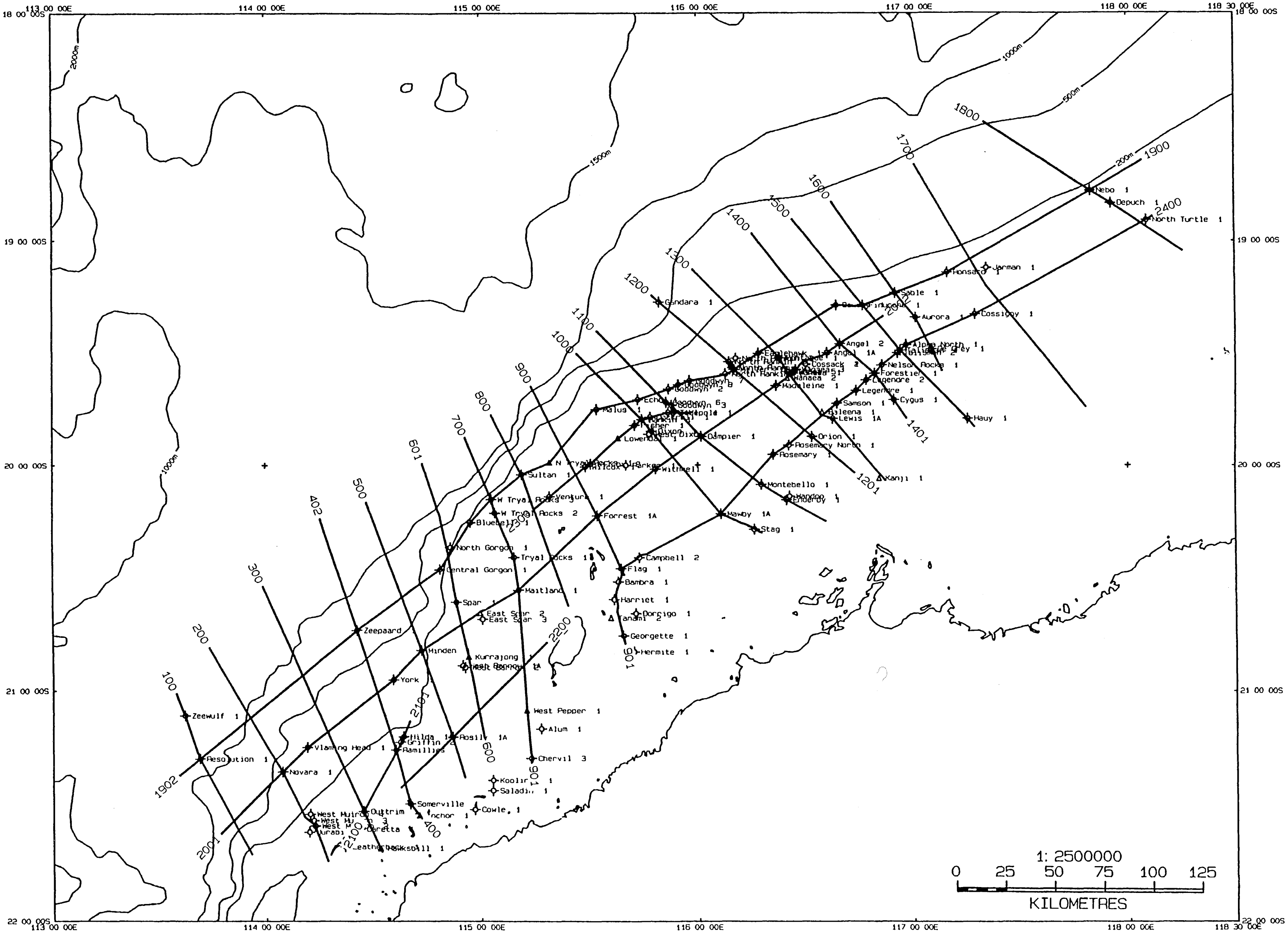


Figure 5 - Survey 136 seismic lines, wells and bathymetry.

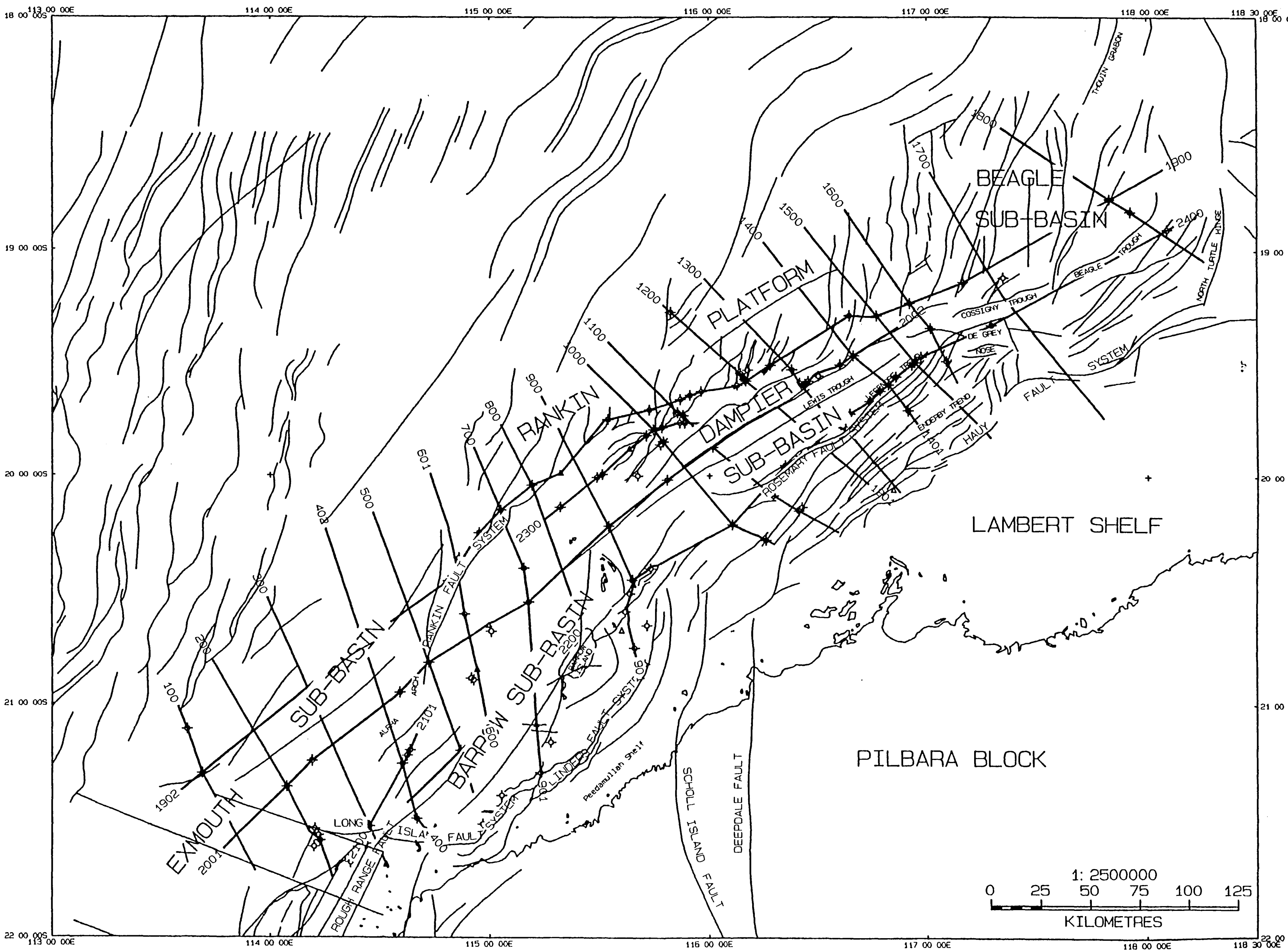


Figure 6 - Survey 136 seismic lines, well locations and structural elements.

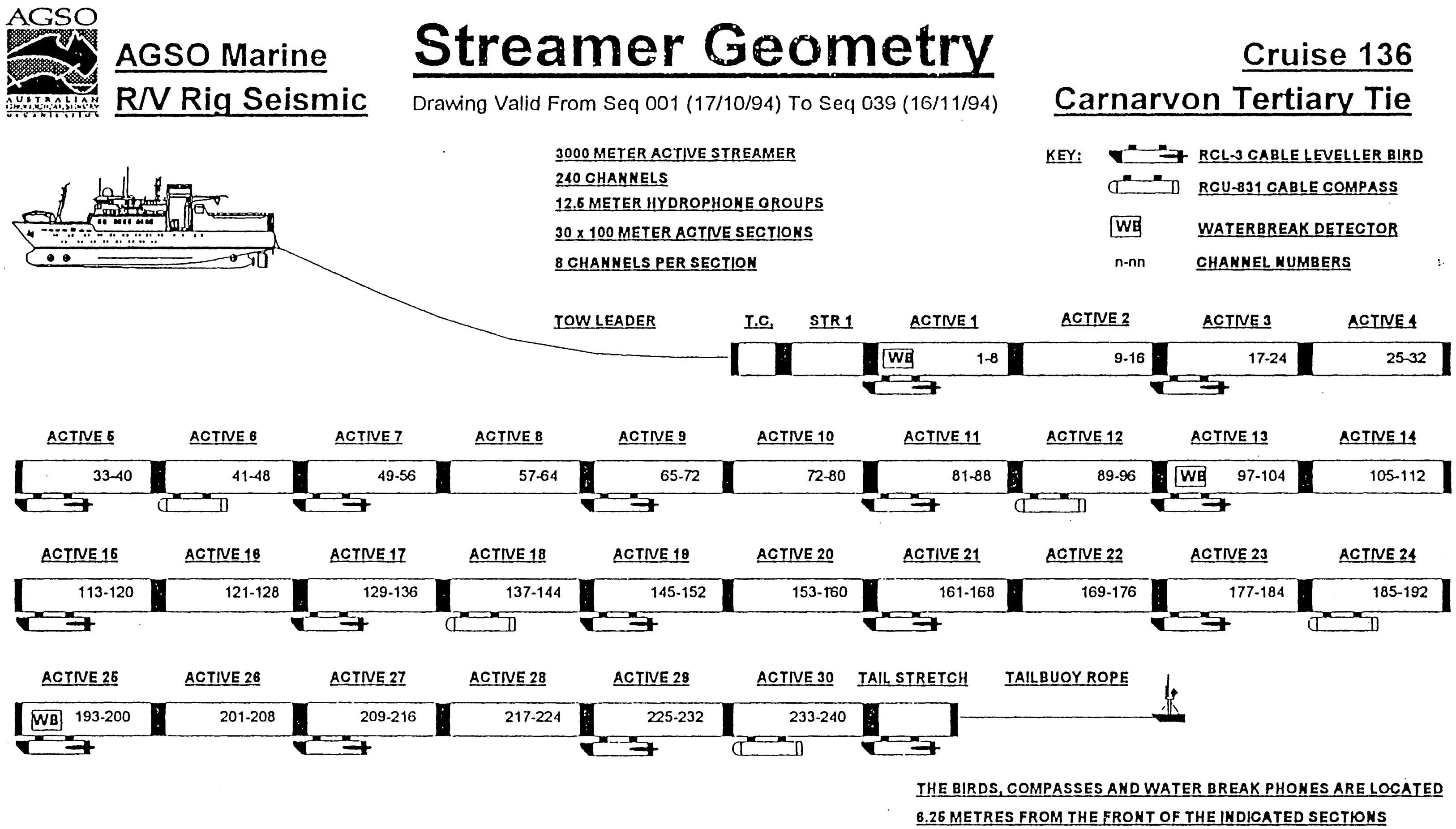


Figure 7 - Streamer configuration for Survey 136.

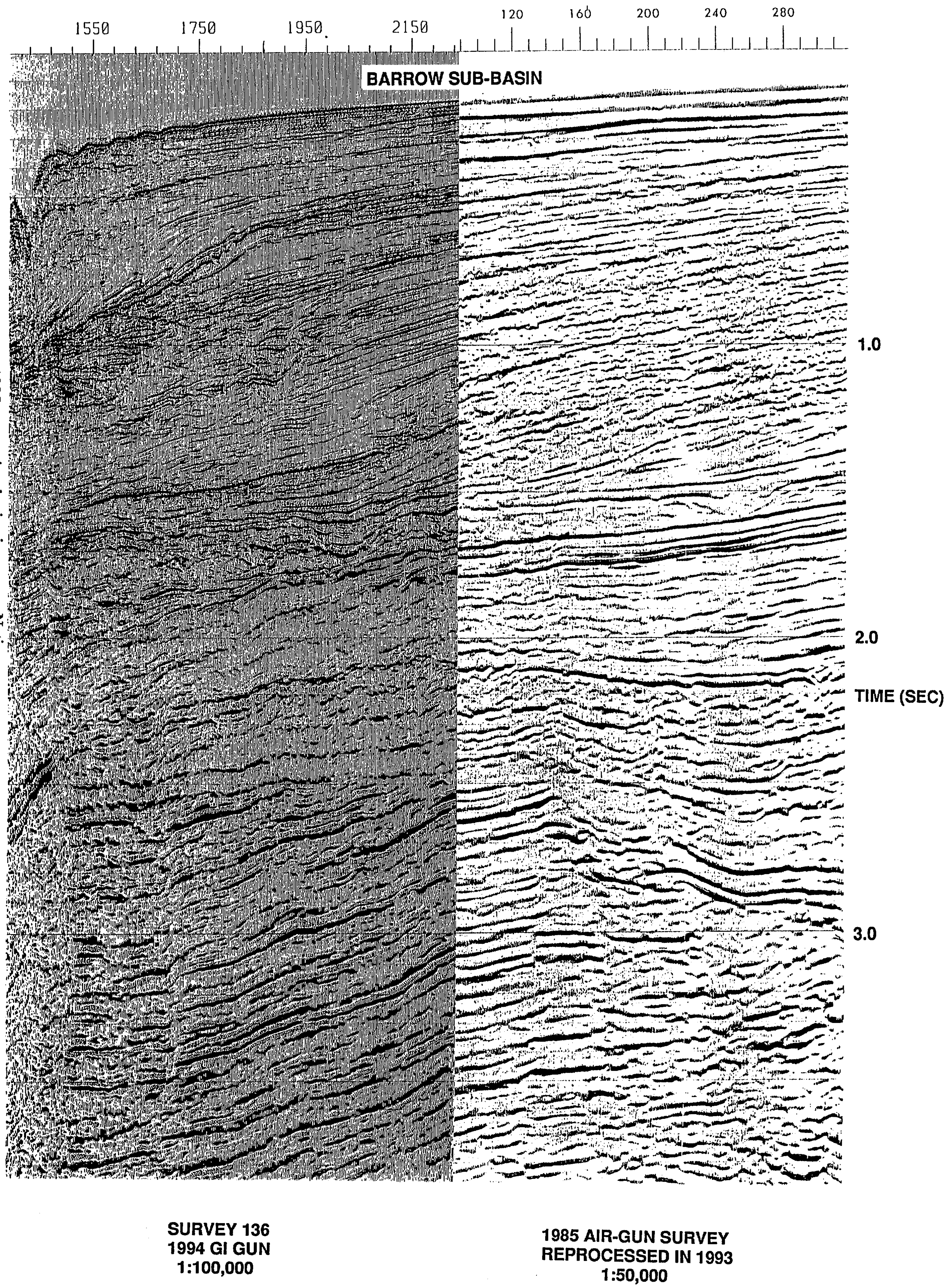


Figure 8 - A portion of Line 136/07 at a line tie to a 1985 conventional seismic survey. Notice the high-frequency content of the survey 136 data.