Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

BMR RECORD 1991/81

ARAFURA SEA - SEISMIC RECONNAISSANCE WITH GEOCHEMISTRY

SURVEY 94

(PROJECT 121.24)

POST CRUISE REPORT

by

P.NAPIER, A.MOORE and J.BRADSHAW

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INTRODUCTION

Large areas of the Arafura Sea in Australian waters are virtually unknown geologically, with seismic coverage being limited to widely separated traverses, some of which have poor sub-seabed penetration.
It was proposed (Moore et al, 1990) that the Rig Seismic be used for one month in early 1990 to carry out reconnaissance of the eastern Arafura Basin. The aims were to investigate the architecture of the graben in the central and western ends of the basin,and to complete the framework of essential reconnaisssance in the sparsely explored and little known eastern portion of the basin and to sample the seawater for traces of thermogenic hydrocarbons, one of the indicators of the generation of hydrocarbons in sub-seafloor sediments.

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

The cruise has pursued these insights with seismic traverses both across and along the Goulburn Graben to acquire data on its deeper structure; with tie lines from the graben northward toward the Australian/Indonesian border; with infill seismic in the eastern part of the basin; with a seismic tie near to Lower Palaeozoic outcrop; and with the acquisition of seismic refraction, magnetic, gravity and dissolved hydrocarbon gas data.

GEOLOGICAL SETTING

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

BRIEF EXPLORATION HISTORY

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

Seismic surveys of regional significance and with good subsurface penetration include:
Wessel Marine Seismic Survey 1972, shot by Western Geophysical for Beaver Exploration, Line identification - WM and W.
M81A Seismic Survey 1981, by GSI for Esso, Line identification - M81.
Arafura Sea S81 Survey 1981, by GSI for Sion Resources, Line identification - S81 AM81 Survey 1981, by GSI for Mincorp, Line identification - AM81.
DS81 Survey 1981, by Western Geophysical for Diamond Shamrock, Line identification DS-81.
DS84 Survey 1984, by Western Geophysical for Diamond Shamrock, Line identification DS-84.

Among the more recent seismic surveys in the area are -
HA88A Seismic Survey by Halliburton for BHP, Line identification HA88A,
PSLA ID 88/43
HA88B Seismic Survey by Halliburton for BHP, Line identification HA88B,
PSLA ID 89/1
HA89A and HA89B, 1989, by Halliburton for BHP, Line identification HA89A and HA89B,

CRUISE OBJECTIVES

The objectives of the cruise were :-

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

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

*to investigate the eastward extent of the Goulburn graben

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

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

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

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

CRUISE DIARY

INTRODUCTION

The R.V.RIG SEISMIC departed Port Darwin at 1600 Hrs. Saturday, 24th February to commence a 30 day scientific cruise to investigate the nature and extent of the sedimentary basins underlying the Arafura Sea.

As stated in the pre-cruise report (Moore et al, 1990) the plan was to build on and extend the knowledge gained through oil exploration primarily since the early 1970's.As can be seen from the list of objectives, most of the cruise period was to be spent extending the present seismic coverage,both in depth and lateral extent.

Also the cruise was, to the best of our knowledge a world first, in that we successfully collected continuous seafloor water samples and carried out geochemical analyses, simultaneously with our seismic coverage. The ability to conduct a geochemical survey in this way has a number of obvious scientific and cost advantages over running independent surveys, not the least of which is the ability to plan immediate infill lines in areas where seismic and geochemical anomalies are co-incident. As a result of the operational success of this cruise using this technique it should be possible to routinely carry out this combined type of survey,in any appropriate area in the future, using the equipment and facilities available on board the R/V RIG SEISMIC.

In addition to the above techniques, continuous underway magnetics and gravity data were recorded and 9 sonobuoys deployed to gather seismic refraction velocities.

OPERATIONAL MODIFICATIONS TO THE ORIGINAL CRUISE PLAN

In general all equipment operated to a satisfactory level to achieve the objectives of the survey, except that some seismic lines (noteably lines K & E, and the eastern half of line J and the northern half of line D) had to be deleted from the program because of equipment downtime and adverse weather. Some lines which were planned in the far northeastern area of the original seismic grid were abandoned because of long transit times and lines 14,15 & 16 were added to those indicated in the pre-cruise report, in order to improve our understanding of the eastern extension of the Goulburn Graben, and complete an integrated data set of this area within the time left available to complete the cruise.

DETAILS OF DATA ACQUIRED

Seismic, magnetics and gravity were recorded on all lines shown in the accompanying map, however geochemical sampling was not carried out on Line 14 and the northern portion of Line 3

ABBREVIATED DAILY LOG

FEBRUARY 24th Departed Port Darwin for survey area.
FEBRUARY 25th Tested DHD equipment and checked continuity,balanced and reconfigured previous 2400m cable.

FEBRUARY 26th Successfully calibrated DHD equipment, added 1200m cable to 2400m cable and tested entire 3600m.
FEBRUARY 27th Problems encountered with starboard towleader, removed and checked. Noisy channels traced.
FEBRUARY 28th Attempted first line start, system and tape drive problems required 2 loops to correct problems. Continual system crashes. May come back and reshoot later.
MARCH 1st Completed Line 1 Transit to Line 2 . Replaced bad depth controller on Bird 18 using Zodiac. Gun buoys detached and had to be retrieved. Commenced Line 2
MARCH 2nd. Series of short computer crashes, 2 compressors with stripped clutches. Completed Line 2.
MARCH 3rd Compressors repaired, guns repaired. Refractor velocity 5600 m/s @ 1.2 secs. TWT . Therefore decided to start shooting Line 3 with single (1600 cu inch) array. Gun controller problems necessitated loop.
MARCH 4th Dual array and 12 second recording begun as approaching Noorthern fault on edge of Goulburn Graben. Completed Line 3. Transit to Line 4.
MARCH 5th Attempted to start Line 4. Repeated Gun Controller problems resulted in no production while problem investigated.
MARCH 6th 2 active sections replaced, shark bites. Gun controller back together. Restarted Line 4.
MARCH 7th More Gun Controller problems. Meeting held and Canberra informed of problems. More work on Gun Controller. Restarted Line 4.
MARCH 8th Record length 11 sec. dual array. Loop in middle of line tape drive hung. Record length reduced to 10 sec @ s.p. 4970. Completed Line 4.
MARCH 9th Began Line 5 experiencing strong currents and high winds. Acquisition suspended, guns retrieved with difficulty, 1 buoy lost.
MARCH 10th Storm continues, no production. Guns being repaired . Heading West back towards start of line 5.
MARCH 11th Weather still poor. Cable deployed however. Steaming back to commence shooting 26 naut. miles from S.O.L.
MARCH 12th Continued shooting Line 5. High velocity refractor very shallow. Strong currents against us. Commenced Line 6. High velocity refractor @ 0.46 TWT. Deployed sonobuoy.
MARCH 13th Computer crash, did loop. Cable rising, data quality deteriorating. Very hard sea floor - audible. Crossed Northern fault of Goulburn Graben.
MARCH 14th Completed Line 6. began Line 7 with 8 sec records. Changed to 12 seconds @ 22 naut. miles from S.O.L. Deployed sonobuoy.
MARCH 15th cable came to surface just prior to GOULBURN -1 Increased speed, reduced record length to 11 sec. Bad navigation satellites, missed well, therefore did a loop. Japanese fishing vessel crossed astern, dived cable and no damage. Completed line 7 Transit to line 8, deployed sonobuoy.
MARCH 16th Began line 8 , had a series of system crashes did a loop. Deployed sonobuoy 4 naut. miles west

of TORRES-1. Completed line 8. Turned onto line 1A
MARCH 17th Completed line 1A. Turned off to start line 9 Had a number system crashes. Sonobuoy deployed.
MARCH 18th Compressor stripped another clutch. Completed line 9. Began line 10. Bulk carrier passed astern. Changing water bottom conditions, louder bang. Began line 11.
MARCH 19th Completed line 11. Started line 12, 8 sec records. Sonobuoy deployed, 3000 m/s and 6000 m/s refractors. Completed line 12. Tugger winch cable snapped on retrieval of guns. No injuries All compressors repaired.
MARCH 20th Started line 13. Initially 96 ch,48 fold, 8 sec. recs, changed to 72 ch, 72 fold, 5 sec. recs @ 78.23.20
MARCH 21st. Completed line 13. Weather had deteriorated. Because of limited time had to abandon lines around Wessel Islands and the link to the West.
MARCH 22nd Lost 1/2 of today because of bad weather. The ship has been heading west to complete the grid at the Eastern edge of the Goulburn Graben. Commenced line 14 in 25 knot winds. Single array 96 ch, 96 fold, 5 sec. recs. Sonobuoy deployed.
MARCH 23rd Completed line 14. Commenced line 15. Single array, 72 ch., 72 fold, 5 sec records. System crash - lost 18 shots. Completed line 15. Began line 16
MARCH 24th Completed line 16. Cable retrieved, headed back to Port Darwin.
MARCH 25th Transit to Port Darwin.
MARCH 26th Berthed Darwin 0800 hrs

DIRECT HYDROCARBON DETECTION (DHD)

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

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

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

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

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

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

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

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

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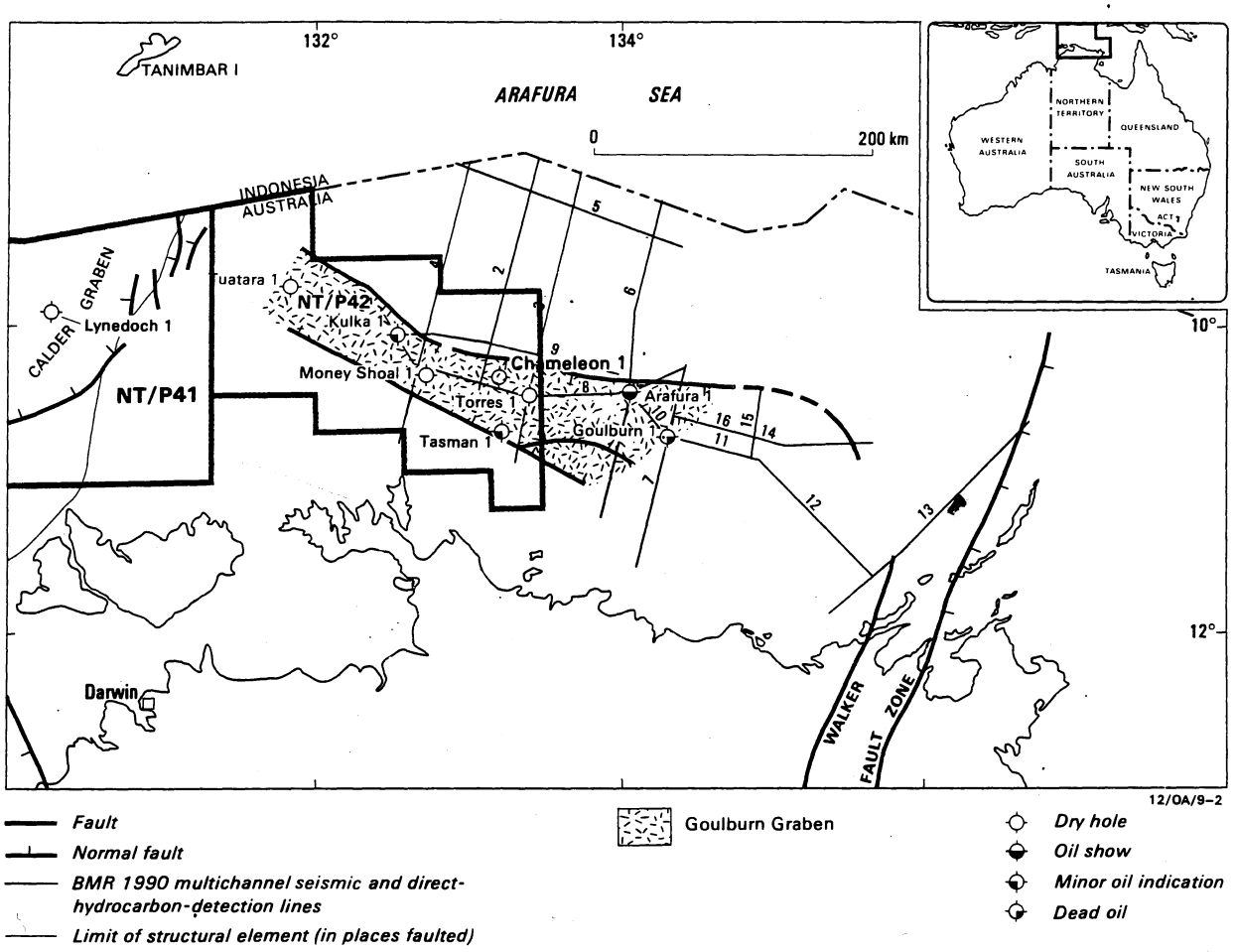

FIGURE 1 SURVEY LOCATION MAP SHOWING THE OUTLINE OF THE GOULBURN GRABEN AND THE SEISMIC LINES OF SURVEY 94

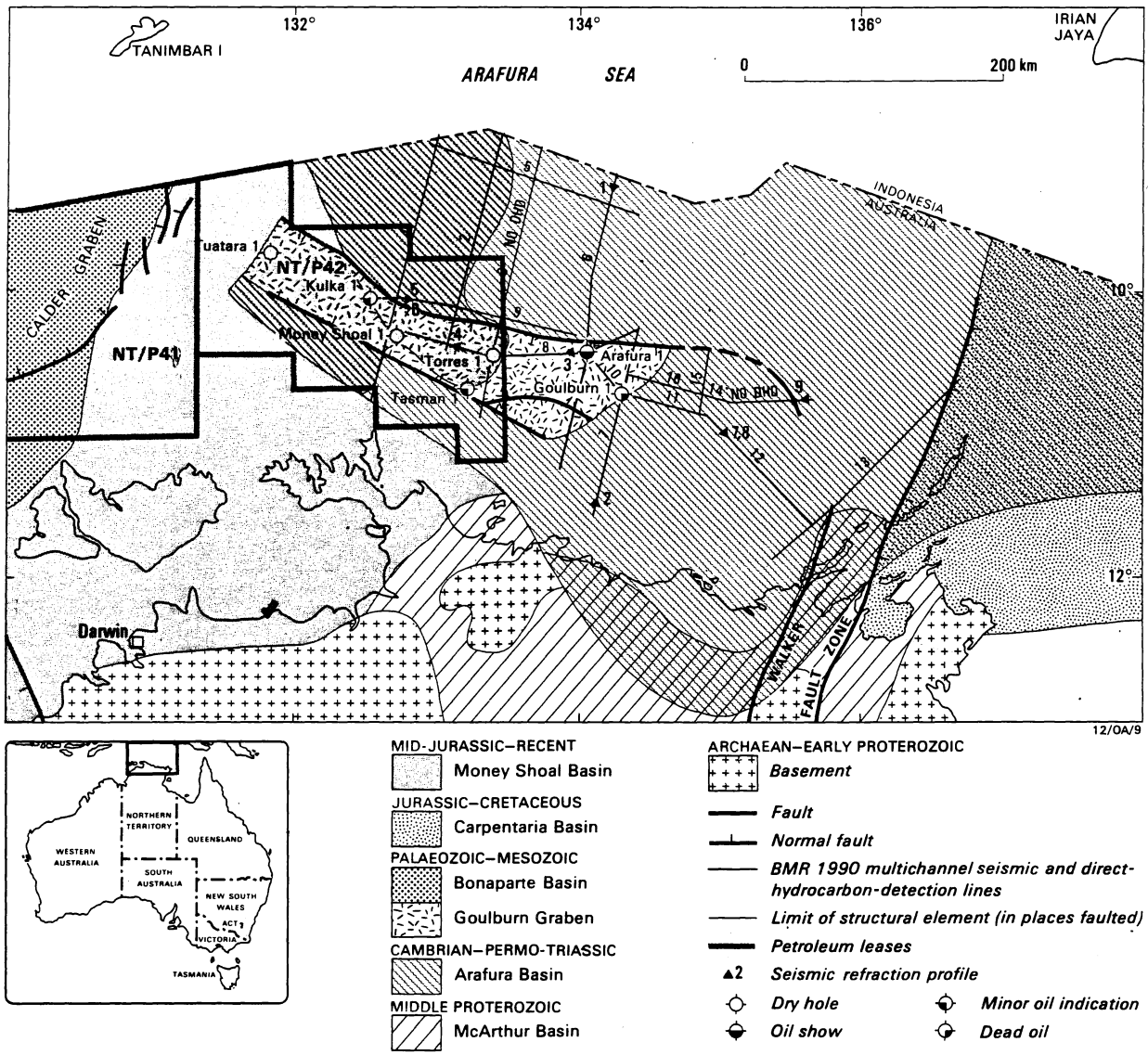

FIGURE 2 STRUCTURAL ELEMENTS MAP OF THE ARAFURA SEA OVERLAIN BY SEISMIC LINES OF SURVEY 94

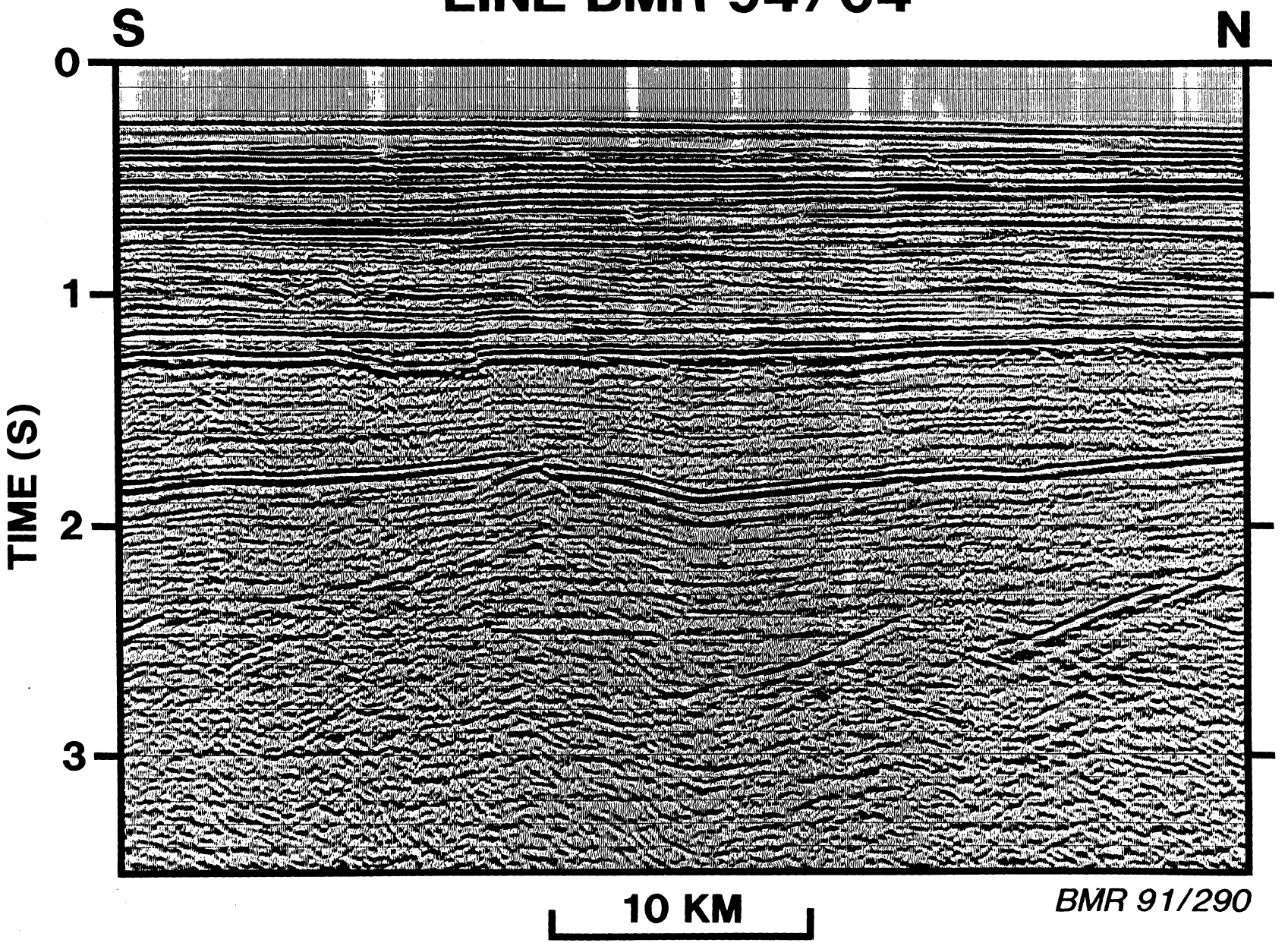

FIGURE 3 SEISMIC SECTION - SHOWING A PORTION OF LINE 4

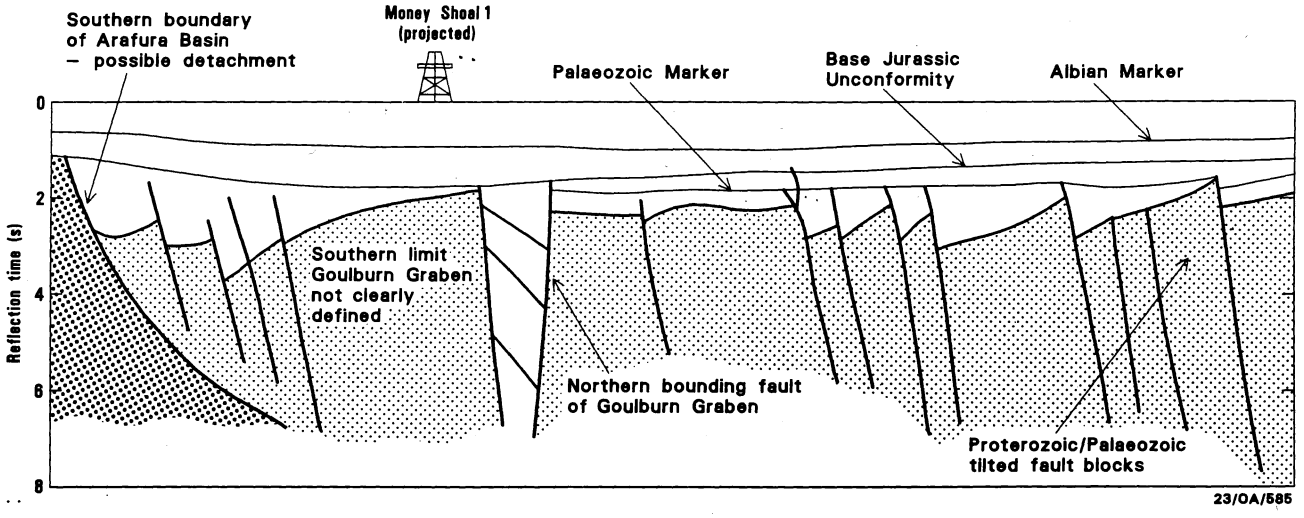

FIGURE 4 LINE DRAWING - SHOWING MAJOR STRUCTURAL FEATURES
LINE 4

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/01

Date: February- March 1990

Start Time: 94.058.1902

Stop Time: 94.059.1714

First SP: 100

Last SP: 2155

Number of shots: 2055

Approx Line length (km): 75

First Field Tape: 94/001

Last Field Tape: 94/019

Number of Field Tapes: 19

Direction of Shooting: SE

Max recording delay: 0 ms

Near Offset: 184 M

Far Offset: 3790 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/01A

Date: February- March 1990

Start Time: 94.075.1232

Stop Time: 94.075.1503

First SP: 100

Last SP: 622

Number of shots: 522

Approx Line length (km): 20

First Field Tape: 94/426

Last Field Tape: 94/431

Number of Field Tapes: 6

Shooting Direction: North West

Max recording delay: 0 ms

Near Offset: 189

Far Offset: 3790

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/02

Date: February- March 1990

Start Time: 94.060.0846

Stop Time: 94.061.0454

First SP: 100

Last SP: 4346

Number of shots: 4246

Approx Line length (km): 170

First Field Tape: 94/020

Last Field Tape: 94/064

Number of Field Tapes: 45

Shooting Direction: North

Max recording delay: 0 ms

Near Offset: 184

Far Offset: 3790

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/03

Date: February- March 1990

Start Time: 94.061.1925

Stop Time: 94.063.0729

First SP: 100

Last SP: 6155

Number of shots: 6098

Approx Line length (km): 225

First Field Tape: 94/065

Last Field Tape: 94/124

Number of Field Tapes: 60

Shooting Direction: South

Max recording delay: 0 ms

Near Offset: 197

Far Offset: 3822

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/04

Date: February- March 1990

Start Time: 94.063.2121

Stop Time: 94.064.0713

First SP: 101

Last SP: 989

Number of shots: 888

Approx Line length (km): 33

First Field Tape: 94/125

Last Field Tape: 94/135

Number of Field Tapes: 11

Shooting Direction: North

Max recording delay: 0 ms

Near Offset: 197 M

Far Offset: 3822 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/4A

Date: February- March 1990

Start Time: 94.065.1248

Stop Time: 94.067.1020

First SP: 100

Last SP: 6260

Number of shots: 6160

Approx Line length (km): 209

First Field Tape: 94/136

Last Field Tape: 94/201

Number of Field Tapes: 66

Shooting Direction: North

Max recording delay: 0 ms

Near Offset: 197 M

Far Offset: 3822 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 64

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/05

Date: February- March 1990

Start Time: 94.067.1415

Stop Time: 94.071.0428

First SP: 100

Last SP: 7024

Number of shots: 6924

Approx Line length (km): 168

First Field Tape: 94/202

Last Field Tape: 94/258

Number of Field Tapes: 57

Shooting Direction: East

Max recording delay: 0 ms

Near Offset: 197 M

Far Offset: 3822 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 64

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/06

Date: February- March 1990

Start Time: 94.071.1130

Stop Time: 94.072.2336

First SP: 145

Last SP: 6706

Number of shots: 6120

Approx Line length (km): 230

First Field Tape: 94/259

Last Field Tape: 94/326

Number of Field Tapes: 68

Shooting Direction: South

Max recording delay: 0 ms

Near Offset: 197

Far Offset: 3800

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 64

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/07

Date: February- March 1990

Start Time: 94.073.0505

Stop Time: 94.074.0534

First SP: 100

Last SP: 4656

Number of shots: 4403

Approx Line length (km): 165

First Field Tape: 94/328

Last Field Tape: 94/374

Number of Field Tapes: 47

Shooting Direction: North

Max recording delay: 0 ms

Near Offset: 189 M

Far Offset: 3790 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 64

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/08

Date: February- March 1990

Start Time: 94.074.1131

Stop Time: 94.075.1232

First SP: 100

Last SP: 6106

Number of shots: 4221

Approx Line length (km): 158

First Field Tape: 94/375

Last Field Tape: 94/425

Number of Field Tapes: 51

Shooting Direction: West

Max recording delay: 0 ms

Near Offset: 189 M

Far Offset: 3790 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/09

Date: February- March 1990

Start Time: 94.075.2006

Stop Time: 94.076.1843

First SP: 100

Last SP: 5067

Number of shots: 4426

Approx Line length (km): 166

First Field Tape: 94/432

Last Field Tape: 94/485

Number of Field Tapes: 54

Shooting Direction: East

Max recording delay: 0 ms

Near Offset: 189 M

Far Offset: 3790 M

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 64 and 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/10

Date: February- March 1990

Start Time: 94.076.1903

Stop Time: 94.077.0310

First SP: 100

Last SP: 1723

Number of shots: 1623

Approx Line length (km): 57

First Field Tape: 94/486

Last Field Tape: 94/503

Number of Field Tapes: 18

Shooting Direction: South East

Max recording delay: 0 ms

Near Offset: 189

Far Offset: 3790

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/11

Date: February- March 1990

Start Time: 94.077.0841

Stop Time: 94.077.1744

First SP: 100

Last SP: 2136

Number of shots: 1943

Approx Line length (km): 73

First Field Tape: 94/504

Last Field Tape: 94/524

Number of Field Tapes: 21

Shooting Direction: East

Max recording delay: 0 ms

Near Offset: 189

Far Offset: 3790

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 10 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 16.2 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/12

Date: February- March 1990

Start Time: 94.077.1831

Stop Time: 94.078.0733

First SP: 120

Last SP: 3216

Number of shots: 3037

Approx Line length (km): 113

First Field Tape: 94/525

Last Field Tape: 94/552

Number of Field Tapes: 28

Shooting Direction: South East

Max recording delay: 0 ms

Near Offset: 189 M

Far Offset: 3790

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 8 Sec

Amplifier Gains: 64

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 15.5 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/13

Date: February- March 1990

Start Time: 94.078.2148

Stop Time: 94.079.2222

First SP: 204

Last SP: 10341

Number of shots: 10137

Approx Line length (km): 183

First Field Tape: 94/553

Last Field Tape: 94/598

Number of Field Tapes: 46

Shooting Direction: North

Max recording delay: 0 ms

Near Offset: 189 M

Far Offset: 3790 M

Group interval: 37.5 M

Cable Active Length: 2660 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 1 x 10 gun arrays, 1800 psi

Number Channels: 72

Recording Fold: 72

Sample Period: 2 ms

Record Length: 5 Sec

Amplifier Gains: 128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 9.1 Sec

Shot Distance: 18.75 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/14

Date: February- March 1990

Start Time: 94.81.0417

Stop Time: 94.81.1619

First SP:600

Last SP:5283

Number of shots:4683

Approx Line length (km):88

First Field Tape: 94/604

Last Field Tape: 94/624

Number of Field Tapes: 21

Shooting Direction: West

Max recording delay: 0 ms

Near Offset: 193m

Far Offset: 2853m

Group interval: 37.5 M

Cable Active Length: 3600 M

Cable Depth: 10 M

Source depth: 10 M

Source Energy: 2 x 10 gun arrays, 1800 psi

Number Channels: 96

Recording Fold: 48

Sample Period: 2 ms

Record Length: 12 and 8 Sec

Amplifier Gains: 128,128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 18.2 or 14.6 Sec

Shot Distance: 37.5 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/15

Date: February- March 1990

Start Time: 94.81.2112

Stop Time: 94.82.0428

First SP: 200

Last SP: 3074

Number of shots: 2853

Approx Line length (km): 53.5

First Field Tape: 94/625

Last Field Tape: 94/638

Number of Field Tapes: 14

Shooting Direction:North

Max recording delay: 0 ms

Near Offset: 193 M

Far Offset:2853 M

Group interval: 37.5 M

Cable Active Length: 2660 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 1 x 10 gun arrays, 1600 cu.in. 1800 psi

Number Channels: 72

Recording Fold: 72

Sample Period: 2 ms

Record Length: 5 Sec

Amplifier Gains: 128,128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 9.1 Sec

Shot Distance: 18.75 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

ARAFURA SEA SURVEY 94 LINELIST

Line: 94/16

Date: February- March 1990

Start Time: 94.82.1026

Stop Time: 94.82.1849

First SP: 5421

Last SP: 8781

Number of shots: 3342

Approx Line length (km): 63

First Field Tape: 94/639

Last Field Tape: 94/653

Number of Field Tapes: 15

Shooting Direction:West

Max recording delay: 0 ms

Near Offset: 193 M

Far Offset:2853 M

Group interval: 37.5 M

Cable Active Length: 2660 M

Cable Depth: 12 M

Source depth: 12 M

Source Energy: 1 x 10 gun arrays, 1600 cu.in. 1800 psi

Number Channels: 72

Recording Fold: 72

Sample Period: 2 ms

Record Length: 5 Sec

Amplifier Gains: 128,128

Filter Settings: 8 Hz low
128 Hz high

Shot Interval: 9.1 Sec

Shot Distance: 18.75 M

Field Tape Density: 6250 bpi

Field Tape Format: SEG-Y (GCR)

APPENDIX 1

CO-ORDINATES OF SEISMIC LINES - WAY POINTS

LATITUDES (SOUTHERN HEMISPHERE IS NEGATIVE)
AND LONGITUDES (EASTERN HEMISPHERE IS POSITIVE)
in degrees minutes and seconds.

1	1	-095530	1322730	
	2	-100342	1323245	KULKA-1 well
	3	-101612	1324025	
2	1	-102538	1330454	
	2	-085550	1332900	
3	1	-090201	1334516	
	2	-102811	1332342	TORRES-1 well
	3	-105334	1331805	
4	1	-104710	1323304	
	2	-101612	1324025	MONEY SHOAL-1 well (7 km to east)
	3	-085727	1330208	
5	1	-085856	1325900	
	2	-092912	1342500	
6	1	-091324	1341616	
	2	-095655	1340524	
	3	-102703	1340326	ARAFURA-1 well
	4	-111511	1335120	
7	1	-113351	1340531	
	2	-104448	1341749	GOULBURN-1 well
	3	-101701	1342522	
8	1	-102703	1340327	ARAFURA-1 well
	2	-102811	1332342	TORRES-1 well
	3	-101612	1324026	
9	1	-100400	1322923	
	2	-100342	1323245	KULKA-1 well
	3	-100321	1324444	
	4	-100730	1330945	
	5	-101742	1335019	
	6	-101942	1335748	
10	1	-102703	1340326	ARAFURA-1 well
	2	-104448	1341749	GOULBURN-1 well
11	1	-104448	1341749	GOULBURN-1 well
	2	-105420	1345500	
12	1	-105420	1345500	
	2	-113912	1353906	Near Elcho Island
13	1	-115243	1352312	
	2	-112638	1355435	
	3	-104030	1364018	

14	1	-104651	1353851
	2	-104800	1350413
	3	-104419	1345115
15	1	-102734	1345519
	2	-105258	1345115
16	1	-104437	1345130
	2	-103616	1342000

SONOBUOY LOG

Sonobuoy No.: 94/01

Seismic Line:94/06

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel: 10

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off PORT/--side

Weather/Sea Conditions: 3

Start Time (GMT): 94.071.1151

Start Water Depth: 100 M

Start Lat: 09° 13.87'S

Start long: 134° 16.218'E

Finish Time (GMT): 94.071.1800

Finish Water Depth: 90 M

Finish Lat/Long:

Finish Shot No.:

Total Time:

Total Distance (Km):

Approx Ship Speed: 4.6 knot

Start Field Tape No:94/260

Stop Field Tape No:94/260

Observations:	Direct Wave	Wide-angle Reflections	Refractions
Yes			
No			

Remarks: Near Indonesian border. Furthest North probe

SONOBUOY LOG

Sonobuoy No.: 94/02

Seismic Line:94/07

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel: 20

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off STB side

Weather/Sea Conditions: 2

Start Time (GMT): 94.073.0850

Start Water Depth: 45 M

Start Lat: 11° 12.855'S

Start Long: 134° 10.063'E

Finish Time (GMT): 94.

Finish Water Depth: M

Finish Lat/Long:

Finish Shot No.:

Total Time:

Total Distance (Km):

Approx Ship Speed: 5 knot

Start Field Tape No:94/335

Stop Field Tape No:94/

Observations:	Direct Wave	Wide-angle Reflections	Refractions
Yes			
No			

Remarks: Near southern margin of Arafura Basin

SONOBUOY LOG

Sonobuoy No.: 94/03

Seismic Line:94/08

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel:

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off STB side

Weather/Sea Conditions: 3

Start Time (GMT): 94.074.1148

Start Water Depth: 60 M

Start Lat: 10^{o} 26.978'S

Start Long: 134^{o} 05.9'E

Finish Time (GMT): 94.

Finish Water Depth: M

Finish Lat/Long:

Finish Shot No.:

Total Time:

Total Distance (Km):

Approx Ship Speed: 4 knot

Start Field Tape No:94/375

Stop Field Tape No:94/

Remarks: 4.5 km West of Arafura-1 well. Ship and source moved off to the West.

SONOBUOY LOG

Sonobuoy No.: 94/04

Seismic Line:94/08

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel:

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off STB side

Weather/Sea Conditions: 3

Start Time (GMT): 94.075.0252

Start Water Depth: 113M

Start Lat: 10.^{o}26.908'S

Start Long: 133^{o}19.061'E

Finish Time (GMT): 94.

Finish Water Depth: M

Finish Lat/Long:

Finish Shot No.:

Total Time:

Total Distance (Km):

Approx Ship Speed: 4 knot

Start Field Tape No:94/375

Stop Field Tape No:94/404

Remarks: 8.8 km WNW of Torres-1 well

SONOBUOY LOG

Sonobuoy No.: 94/06

Seismic Line:94/09

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel:

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off Port side

Weather/Sea Conditions: 3

Start Time (GMT): 94.076.0330

Start Water Depth: 89M

Start Lat: $10^{o}05.373'S$

Start Long: $132^{o}56.887'E$

Finish Time (GMT): 94.76.1207

Finish Water Depth: 71M

Finish Lat/Long: $12^{o}12.9'S$
$133^{o}32.0'E$

Finish Shot No.:

Total Time: 8hr37min

Total Distance (Km): 67

Approx Ship Speed: 4.1 knot

Start Field Tape No:94/449

Stop Field Tape No:94/468

Remarks: Probe no.5 went bad after 30 minutes, and no.6 was launched to replace it. Probe 6 is located on the upthrown side of the northern bounding fault of the Goulburn Graben, near the fault, and just to the north of it. The ship and source moved off to the East, parallel to the fault.

SONOBUOY LOG

Sonobuoy No.: 94/08

Seismic Line:94/12

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel:

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off STB side

Weather/Sea Conditions: 3

Start Time (GMT): 94.077.182442

Start Water Depth: 50M

Start Lat:

Start Long:

Finish Time (GMT): 94.78.020015

Finish Water Depth: 37 M

Finish Lat/Long:

No. of shots: 1322

Total Time:

Total Distance (Km):

Approx Ship Speed: 4.7 knot

Start Field Tape No:94/525

Stop Field Tape No:94/541

Remarks: Probe no.7 failed. Probe 8 was launched to replace it. Probe 8 is located near latitude 11^{o}S, longitude 135^{o}E. The ship and source moved off to the southeast, toward the outcrop of Cambrian rocks on Elcho Island.

SONOBUOY LOG

Sonobuoy No.: 94/09

Seismic Line:94/14

Sonobuoy Model: REF-TEK-2

Receiver Model: Yaesu

Sonobuoy channel:

Seismic Channel: 97

Hydrophone Depth: 60ft.(18.3m)

Duration (Hrs):

Filter : 6 Hz Low - 128 Hz High

Recording Delay: 0 ms

Launched off Port side

Weather/Sea Conditions: 6

Start Time (GMT): 94.081.0439

Start Water Depth: 60M

Start Lat: $10^{o}45.475'S$

Start Long: $135^{o}36.588'E$

Finish Time (GMT): 94.

Finish Water Depth: M

Finish Lat/Long:

Finish Shot No.:

Total Time:

Total Distance (Km):

Approx Ship Speed: 4 knot

Start Field Tape No:94/604

Stop Field Tape No:94/404

Remarks: Farthest east. North of the Graben. Ship and source moved off to the West. Sea conditions marginal.

APPENDIX 2: List of Geophysical Equipment

Seismic System

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

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

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

Sonobuoys
- Ref-Tek-2, deploying one hydrophone to 18.2m depth

Bathymetric System

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

Gravity Meter

- Bodenseewerk Geosystem KSS - 31 marine gravity meter

Magnetometer

- Geometrics G801/803 proton precession magnetometer

Navigation Systems

GPS System - Magnavox T-Set GPS navigator

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

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

Data Acquisition System

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

APPENDIX 3

ACQUISITION PARAMETERS

Source	2x1600 cubic inch air-gun arrays 1x1600 " " " " (lines 13-16)
Shot Spacing	37.5m (lines 1 - 12) 18.75m (lines 13 - 16)
Shooting Interval	18.2 seconds at 4 knots 14.6 " " 5 " 9.1 " " 4 " (lines 14 - 16)
Cable Length	3600m active; 4200m to tail buoy 2660m active (lines 13-16)
Group Interval	37.5m
No. of Channels	96 (lines 1 - 12) 72 (lines 13 - 16)
Near Offset	approx. 200m
Far Offset	approx. 3800m (lines 1 - 12) 2853 (lines 13 - 16)
Cable Depth	10 - 12m
Recording Fold	48 (lines 1 - 12) 72 (lines 13 - 16)
Record Length	12,10,8 seconds 5 seconds (lines 13 - 16)
Sample Rate	2 milliseconds
Filter Settings	8 Hz Low cut; 128 Hz High cut
Amplifier Gain	Pre-amplifiers 128 Hz. IFP used on all lines
Field Tape Density	6250 bpi
Tape Format	SEG Y

APPENDIX 4: Science Personnel

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