AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Record Number

DEEP STRUCTURE OF THE JOINT DEVELOPMENT ZONE AND ADJACENT AREAS, TIMOR SEA:

CRUISE PROPOSAL

Project 121.36

C J Pigram

AGSO Record 1992/95

AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION
Marine Geoscience and Petroleum Geology Program

DEEP STRUCTURE OF THE JOINT DEVELOPMENT ZONE AND ADJACENT AREAS, TIMOR SEA:

CRUISE PROPOSAL

Project 121.36

C J Pigram

AGSO Record 1992/95

Inquiries should be directed to the Principal Information Officer, Australian Geological Survey Organisation, GPO Box 378, Canberra, ACT 2601

ISSN: 1039-0073
ISBN: 0 642 18601 4

CONTENTS

APPENDICES

FIGURES

1. Location of the Joint Development Zone and adjacent areas showing the location of the wells drilled in the area.
2. Map showing the approximate location of the deep crustal lines shot across the Banda Arc by BIRPS in 1992.
3. Structural framework map of the JDZ and adjacent regions
4. Stratigraphic column for the JDZ and adjacent regions (from Botten and Wulf, 1990)
5. Track map of the JDZ and adjacent regions showing proposed lines.
6. Structural elements map with proposed lines.

EXECUTIVE SUMMARY

The Joint Development Zone (JDZ) and adjacent areas cruise is part of a program being undertaken by AGSO, to determine the structural architecture of the northwestern margin of Australia and the influence of structuring on the location, migration and trapping of hydrocarbons in the region. The major objectives of the cruise are:

1) to determine the regional structural framework of the eastern Timor Sea region by examining the boundaries between the major structural elements along a series of transects;

2) to provide modern regional seismic tie lines through key wells in the region to facilitate province-wide correlations;

3) to determine the deep crustal structure of the Sahul Syncline, Sahul Platform, Timor Trough and Malita Graben;

4) to examine the effects of the deep crustal structure and their various phases of reactivation on the strutural development of the region.

To meet these objectives it is proposed that the R V Rig Seismic collect approximately 2600 km of deep crustal (16 sec record length) multichannel seismic and other geophysical data along 13 lines in and around the JDZ. The proposed lines tie major wells in the region. Where possible the lines are orthogonal to the principal trends in the region. Some strike lines are included to assist the regional ties between wells and existing data sets. Details of the lines are as follows:

Line 1: Sahul Syncline strike line and Timor Trough dip line - ties Kite - 1.

Line 2: Dip line western end of Malita Graben Sahul Syncline intersection- ties Harbinger -1, Shalimar -1 and Flamingo -1.

Line 3: Tie line to Survey 100.

Line 4: Dip line across Sahul Platform and Timor Trough. Extends BMR Line 100/5 to form complete margin transect.

Line 5: Dip line across Malita Graben and Sahul Platform - ties Jacaranda -1 and Curlew -1 and into BMR Survey 100.

Line 6: Dip line - ties Sunrise -1, Troubador -1 and Shearwater -1.

Line 7: Strike Line along Malita Graben - ties Kite and Survey 100.

Line 8: Strike line northern flank of Malita Graben - ties Halcyon -1 and Shearwater -1.

Line 9: Extends Survey 98 line and ties Avocet -1A and Flamingo -1.

Line 10: Extends Survey 98 line.

Line 11: Strike line along northern edge of Sahul Platform and southern flank of Timor Trough.

The program suggested here assumes a 30 day cruise. The program allows for bad weather and other contingencies and should be achievable in the time frame.

INTRODUCTION

The Marine Geoscience and Petroleum Geology Program (MGPG) of AGSO began a program of deep seismic acquisition (up to 16 sec twt record length) along the north western margin of Australia in 1990 with the intention of acquiring a complete, consistent regional data set covering the region from North West Cape to the western Arafura Sea by 1993/94. This portion of the Australian margin was seen to be the most prospective region outside of the Bass Strait Basins and to be a likely major source of Australia's future hydrocarbon supplies. Portions of this margin have been explored in detail since the 1960's but there has little recent analysis of the regional structural framework using either modern extensional tectonic concepts for the formation of the margin (eg Lister et al., 1991) or modern collisional tectonic concepts (eg Beaumont, 1980; Allen and Homewood, 1986) for the deformation of parts of this margin. The MGPG program on the north west margin of Australia is designed to establish the gross architecture of the margin by imaging the margin forming structures and examining their reactivation histories through time. This information will be critical in developing new exploration strategies, and will assist future basin framework and resource studies of the region. To address the margin structural framework problems of this region, the following cruises have been undertaken or are planned:

1) Vulcan Graben (Survey 98) - 1900 km of deep seismic data - acquisition completed December 1990 (O'Brien and Williamson, 1990).

2) Petrel Sub-basin (Survey 100) - 2090 km of deep seismic data - acquisition completed May 1991 (Willcox & Ramsay, 1991).

3) North Carnarvon Basin I (Survey 101) - 1654 km of km of deep seismic data - acquisition completed June 1991 (Stagg & others, 1991).

4) North Carnarvon Basin II (Survey 110) - 2868 km of deep seismic data - acquisition completed July 1992 (Stagg 1992).

5) Australian - Indonesian Joint Development ZOne and adjacent areas - 2600 km (this proposal) - acquisition early 1993.

6) Malita Graben - 2500 km proposed - acquisition during early 1993.

7) Browse Basin - 2500 km proposed - acquisition during mid 1993.

8) Offshore Canning - 2500 km proposed - acquisition during mid 1993.

9) Scott Plateau- Roti Basin - 2500 km proposed - acquisition during late 1993.

On completion of this program of data acquisition there will be a network of over 20 000 km of deep crustal seismic data linking all the major structural elements of the north western margin.

The JDZ and adjacent areas cruise will gather data from the Timor Sea including two transets across the Timor Trough. It will tie to Surveys 98 and 100 and when combined with Line 100/5 will provide a complete margin transect from near Timor across the Timor Trough, Sahul platform to the southeastern part of the Petrel Sub-basin.

EXPLORATION HISTORY

Exploration activity in the region began in the early 1960's when two consortia headed by Woodside and by ARCO won concessions covering most of the offshore Bonaparte and Browse Basins. Seismic acquistion began in 1964 and the first exploration well (Petrel -1) was drilled by ARCO in 1970 resulting in the discovery of the Petrel Gas Field. Gull -1 was also drilled in 1970 to test a large salt induced feature. It was plugged and abandoned after encountering minor hydrocarbons at several levels. Flamingo -1, which is the only well in Zone of Co-operation A (ZOCA), was drilled in 1971 to test a horst structure on the flank of the Sahul Syncline. The well is interpreted to have intersected a net 57 m thick gas accumulation in sandstones of Late Jurassic Flamingo Group and live oil from the middle Jurassic Plover Formation (Botten and Wulf 1990). The well is now thought to have been off structure. The well was plugged and abandoned as being non-commercial. When exploration ceased in the the region approximately 20 000 km of seismic data had been obtained.

With the Timor Gap not available to exploration during the late 1970's and 1980's considerable exploration activity occurred to the west in and around the Vulcan Graben leading to the discovery of several commercial fields.

With the completion of an agreement between the Australia and Indonesia Governments to form a Zone of Cooperation, the Timor Gap was reopened for exploration for the first time since the late 1970's. ZOCA of the Joint Development Zone (JDZ) is currently the site of considerable exploration activity. In the 14 permit areas already leased exploration companies have committed to an intensive program of almost 500 000 km of seismic data and a minimum of 41 wells over the next 6 years. The first well is expected to be spudded in late 1992.

Other Deep Crustal Surveys - BIRPS.

In early 1992 the British Institutions Reflection Profiling Syndicate (BIRPS) in conjunction with Marine Geoscience Institute of Indonesia (MGI) conducted a deep crustal survey (+20 sec records) across the Banda Arc to the east of Timor (Fig. 2). These lines finished on the outer shelf just within Australian waters but will be extended across the shelf by AGSO during the proposed East Malita cruise scheduled for early 1993.

REGIONAL STRUCTURE

The JDZ and adjacent areas region lies within that part of the northwestern margin of Australia that now forms the foreland to the Timor collision zone. It includes the Timor Trough and Malita Graben which are separated by the Sahul Platform. The southwestern end of the Sahul Platform is cut by NW-SE trending Sahul Syncline which separates the region from the Vulcan Sub-basin and Londonderry High region of the the southern Timor Sea region (Fig. 3). Major structuring culminated in the late Permian or Triassic to form the gross architecture of the margin. Many, if not all of the structures, formed at this time have since been reactivated on several ocassions during the Mesozoic and Cainozoic.

STRATIGRAPHY

The stratigraphy of the region is poorly known due to the sparsity of wells. Consequently and the nomenclature used is usually that of the Bonaparte Basin. A summary of the stratigraphy of the region is shown in Fig. 4. The thickness and age of sedimentary packages varies with structural provinces. Permian sediments have been intersected in Troubadour -1, Petrel and Tern wells. Major potential reservoirs in the region are Late Jurassic/Cretaceous sandstones of the Flamingo Group, although Botten and Wulf (1990) list a total of 8 sandstone horizons ranging from Triassic to Eocene in age, that they believe have potential as reservoirs. The major regional seal in the Timor Sea region is Cretaceous Bathurst Island Formation. Potential source rock intervals are known from the Early to Middle Jurassic Plover Formation, the Flamingo Group and the basal Bathurst Island Formation. Regionally the Plover Formation is known to contain good source rock beds that are currently mature.

OBJECTIVES AND SPECIFIC PROBLEMS

The major objectives of the JDZ and adjacent areas cruise are:

1) to determine the regional structural framework of the region by examining the boundaries between the major structural elements along a series of transects;

2) to provide modern regional seismic tie lines through the key wells in the region to facilitate province-wide correlations;

3) to determine the deep crustal structure of the Malita Graben, Sahul Syncline, Sahul Platform and Timor Trough;

4) to examine the effects of the deep crustal structure and the various phases of reactivation on the formation and preservation of petroleum traps;

5) to use the structural information as an aid to defining probable migration history and its influence on the trapping of hydrocarbons.

More specifically the project has been designed to examine the following problems related to the structural development of the central Timor Sea region.

- to examine the structural relationship of the Sahul Syncline to the surrounding platforms.

- examine the structural development of the Sahul Platform.

- determine the timing and style of reactivation of the major structures.

- examine the age and nature of the movement on the bounding structures of the Malita graben. In particular, determine the role of the Timor collision in the reactivation history of the region, and the migration routes for hydrocarbons.

- determine the pre-collisional nature of this segment of the margin in terms of its upper or lower plate affinities as described in detachment models for margin formation (eg Lister et al., 1990) - determining the pre-collisional nature of the margin may be essential for predicting the nature of the collision-induced reactivation of the margin forming structures.

PROPOSED PROGRAM

The proposed lines for the JDZ and adjacent areas survey are shown in Figures 5 - 7. These lines total 2593 km and tie all the wells in the JDZ as well as key wells to the east and west. The location and orientation of the lines shown here are follows discussion with permit holders but are preliminary and may be changed following further consultation with permit holders, designated authorities and other interested groups. Overall, the lines are designed to examine the major structural elements in the region. Where possible the lines are orthogonal to the principal trends in the region. Some strike lines are included to assist the regional ties between wells.

A summary of the lines and their specific objectives related to it follows. Way points for each line are listed in Appendix 2.

- **Line 1:** Sahul Syncline strike line and Timor Trough dip line - ties Kite - 1
- **Line 2:** Dip line western end of Malita Graben, Sahul Syncline intersection- ties Harbinger - 1, Shalimar - 1 and Flamingo - 1
- **Line 3:** Tie line to Survey 100
- **Line 4:** Dip line across Sahul Platform and Timor Trough. Extends Line 100/5 to form complete margin transect.
- **Line 5:** Dip line across Malita Graben and Sahul Platform - ties Jacaranda - 1 and Curlew - 1 and into Survey 100.
- **Line 6:** Dip line - ties Sunrise - 1, Troubador - 1 and Shearwater - 1.

- **Line 7:** Strike Line along Malita Graben - ties Kite - 1 and Survey 100
- **Line 8:** Strike line northern flank of Malita Graben - ties Halcyon -1 and Shearwater -1
- **Line 9:** Extends Survey 98 and ties Avocet -1A and Flamingo -1
- **Line 10:** Extends Survey 98
- **Line 11:** Strike line along northern edge of Sahul Platform and southern flank of Timor Trough

REFERENCES

Allen, P. A. and Homewood P. 1986. Foreland Basins. *International Association of Sedimentologist Special Publication* No.8. Oxford (Blackwell) 453pp.

Beaumont, C. 1981. Foreland Basins. *Geophysical Journal of the Royal Astronomical Society*, 65, 291-329.

Botten, P. and Wulff, K. 1990. Exploration potential of the Timor Gap Zone of Co-operation. *APEA Journal*, 68-90.

Durrant, J. and Young, A., 1988. A case study of seismic exploration in the Offshore Bonaparte Basin. In Purcell, P.G. and R.R. (Eds.), The North West Shelf, Australia: *Proceedings of Petroleum Exploration Society Australia Symposium*, Perth, 489 - 498.

Lister, G.S., Etheridge, M.A., and Symonds, P.A., 1991. Detachment models for the formation of passive continental margins. *Tectonics* 10, 1038-1064.

Mory, A. J., 1991. Geology of the offshore Bonaparte Basin, North western Australia. *Geological Survey of Western Australia Report* 29, 47p.

Northern Territory Geological Survey, 1990. Petroleum Basin Study: Bonaparte Basin. *Northern Territory Geological Survey, Ref No. GS 90/ 010.*

O'Brien, G. W. and Williamson, P.E. 1990. Research Cruise proposal. Vulcan Graben, Timor Sea: deep crustal structure, structural reactivation, aeromagnetics, and hydrocarbon migration. *Bureau Mineral Resources, Geology and Geophysics, Australia, Record* 1990/91.

Stagg, H.M.J. 1992. Deep structure of the Southern North west Shelf: SNOWS-II (survey 110) Post - cruise report. *Bureau Mineral Resources, Geology and Geophysics, Australia, Record* 1992/60.

Stagg, H. M. J., Brassil, F.M., and Survey 101 Shipboard Party, 1991. Deep structure of the southern North west shelf - post cruise report. *Bureau Mineral Resources, Geology and Geophysics, Australia, Record* 1991/79.

Willcox, J.B. and Ramsay, D.C., 1991. Deep structure of the Bonaparte Basin Regional Petrel subbasin cruise: operational report. *Bureau Mineral Resources, Geology and Geophysics, Australia, Record* 1991/45.

APPENDIX 1

WELLS TO BE TIED DURING JDZ AND ADJACENT AREAS SURVEY

WELL	OPERATOR	DATE	TD m	OLDEST SEQUENCE	STATUS
FLAMINGO - 1	ARCO	1971	3700	JURASSIC	gas and oil shows
CURLEW -1	ARCO	1975	2035	JURASSIC	gas and oil shows
SHEARWATER 1	ARCO	1974	3177	JURASSIC	dry
SUNRISE - 1	BOCAL	1975	2341	JURASSIC	gas/cond
TROUBADOUR	BOCAL	1974	3459	PERMIAN	gas/cond
JACARANDA - 1	TRICENTROL	1984	3783	JURA/CRET	gas and oil shows
AVOCET - 1A	BOND	1986	2217	JURASSIC	gas and oil shows
HALCYON - 1	LASMO	1991	2090	TRIASSIC	gas
KITE -1	WMC	1990	2310	JURASSIC	dry
SHALIMAR - 1	KUFPEC	1992	2756	JURASSIC	minor shows
HARBINGER -1	KUFPEC	1991	2765	JURASSIC	dry

APPENDIX 2

WAY POINTS

line	wells	pt	latitude	longitude
NOP01		1.00	-12.17000000	126.46000000
KITE 1		2.00	-12.06779300	126.43676100
		3.00	-09.22000000	125.63000000
NOP02		1.00	-12.35000000	126.82000000
HARBINGER 1		2.00	-12.21999800	126.74477600
SHALIMAR 1		3.00	-12.03708300	126.65108300
FLAMINGO 1		4.00	-11.02611100	126.48194400
		5.00	-09.87000000	126.01000000
NOP03		1.00	-12.37000000	127.55000000
		2.00	-11.28000000	127.00000000
NOP04		1.00	-11.32000000	127.61000000
		2.00	-10.65000000	127.11000000
		3.00	-09.00000000	126.27000000
NOP05		1.00	-11.85000000	128.30000000
CURLEW 1		2.00	-11.77055600	128.26388800
JACARANDA 1		3.00	-11.47083500	128.16388000
		4.00	-10.14000000	127.88000000
		5.00	-09.24000000	127.46000000
NOP06		1.00	-10.93000000	128.40000000
SHEARWATER 1		2.00	-10.51361100	128.31027800
TROUBADOUR 1		3.00	-09.73439400	128.12375300
SUNRISE 1		4.00	-09.59009700	128.15378900
		5.00	-09.50000000	128.18300000
NOP07		1.00	-12.12000000	126.35000000
KITE 1		2.00	-12.06779300	126.43676100
		3.00	-11.43000000	127.66000000
		4.00	-10.78000000	128.46000000
NOP08		1.00	-11.95000000	125.38000000
HALCYON 1		2.00	-11.93779400	125.47171900
		3.00	-11.28000000	127.58000000
SHEARWATER 1		4.00	-10.51361100	128.31027800
		5.00	-10.42000000	128.37000000
NOP09		1.00	-11.41000000	125.67000000
AVOCET 1A		2.00	-11.37281300	125.75500100
FLAMINGO 1		3.00	-11.02611100	126.48194400
		4.00	-10.98000000	126.56000000
NOP10		1.00	-10.90000000	125.60000000
		2.00	-10.65000000	125.84000000
		3.00	-10.55000000	126.05000000
NOP11		1.00	-10.08000000	125.78000000
		2.00	-9.25000000	127.78000000

APPENDIX 3
LINE LENGTHS

JDZ AND ADJACENT AREAS

All distances are measured in kilometres.

Line	Dist	Line	Dist	Line	Dist	Line	Dist
NOP01	339.03	NOP04	296.61	NOP07	275.10	NOP10	63.70
NOP02	290.64	NOP05	304.61	NOP08	380.06	NOP11	238.01
NOP03	134.66	NOP06	162.39	NOP09	108.35		

TOTAL: 2593.15 kilometres.

Additional line length proposed by JDA on 15/11/92 = approximately 300 km

Probable Shooting Sequence

7 (shoot to SW) $\Rightarrow$ 1 $\Rightarrow$ 2 $\Rightarrow$ 3 $\Rightarrow$ 4 $\Rightarrow$ 5 $\Rightarrow$ 6 $\Rightarrow$ 11 $\Rightarrow$ 10 $\Rightarrow$ 9 $\Rightarrow$ 8

APPENDIX 4

SEISMIC ACQUISITION PARAMETERS

Seismic Cable Configuration

standard	length 4800 m	
	group length	25 m
	no. channels	192

Seismic Source

	airgun array capacity	50 litres (3000 cu in)
	airgun pressure	1800 psi (normal)
		1600 psi (minimum)
	shot interval	19.4 sec @ 5 knots
		21.6 sec @ 4.5 knots

Fold

	standard	4800 %

Recording Parameters

	record length	16 s
	sample interval	2 ms

Research Vessel Rig Seismic

R.V. *Rig Seismic* is a seismic research vessel with dynamic positioning capability, chartered and equipped by BMR to carry out the Continental Margins Program. The ship was built in Norway in 1982 and arrived in Australia to be fitted out for geoscientific research in October 1984. It is registered in Newcastle, New South Wales, and is operated for BMR by the Australian Maritime Safety Authority.

Gross Registered Tonnage:			1545 tonnes
Length, overall:			72.5 metres
Breadth:			13.8 metres
Draft:			60 metres
Engines:	Main:	Norma KVMB-12	2640 H.P./825 r.p.m.
	Aux:	3 x Caterpillar	564 H.P./482 KVA
		1 x Mercedes	78 H.P./56 KVA
	Shaft generator:	AVK 1000 KVA; 440 V/60 Hz	
	Side Thrusters:	2 foward, 1 aft, each 600 H.P.	
	Helicopter deck:	20 metres diameter<R>	
	Accommodation:	39 single cabins and hospital	

Scientific equipment

FJORD Instruments seismic receiving array: 6.25 m, 12.5 m, 18.75 m and 25 m group lengths, up to 288 channels; up to 6000 metres active streamer length

Syntron RCL-3 cable levellers; individual remote control and depth readout

Haliburton Geophysical Service 32 x 150 cubic inch airguns in two 16 gun arrays; the normal operating array is 2 x 10 guns, giving a total of 3000 cubic inches normal operating array volume

Seismic Systems S-15 and S-80 high resolution water gun array consisting of 5 x 80 cubic inch

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 BMR running on DEC μ VAX 3500:

- 0.5msec-4msec sampling interval, 2sec-16sec record length
- Phoenix A/D converter and instantaneous floating point amplifier
- Data stored on Fujitsu 3480 cartridge tape drives
- Data in demultiplexed (modified) SEG-Y format.

Reftek and Yaesu sonobuoy receivers

Raytheon echo sounders: 3.5 KHz (2 K.W.), 16 transducer sub bottom profiler and 12 KHz (2 K.W.)

Geometrics G801/803 magnetometer/gradiometer

Bodenseewerk Geosystem KSS-31 marine gravity meter

E.G. & G. model 990 sidescan sonar with 1000 m of cable

Nichiyu Giken Kogyo model NTS-11AU heatflow probe

Australian Winch and Haulage deepsea winch with 10 000 metres of 18 mm wire rope and hydrographic winch with 4000 m of 6 m wire rope

Coring and rock dredging systems (various) and vibracorer

Light hydrocarbon extractor and gas chromatographs for continuous DHD (direct hydrocarbon detection) in bottom water

Hydrocarbon gas analyses in sediments

Geochemical analysis equipment for environmental monitoring.

15 metre A frame with a 12.5 ton load capability, using a variety of winches, supporting towed arrays and future capability for large scale deep coring and drilling

Navigation equipment

Magnavox T-Set Global Positioning System navigator

Magnavox MX 1107RS and MX 1142 transit satellite receivers

Magnavox MX 610D and Raytheon DSN 450 dual axis sonar dopplers

Sperry, Arma Brown and Robertson gyro-compasses; plus Ben paddle log

RACAL SKYFIX differential GPS system

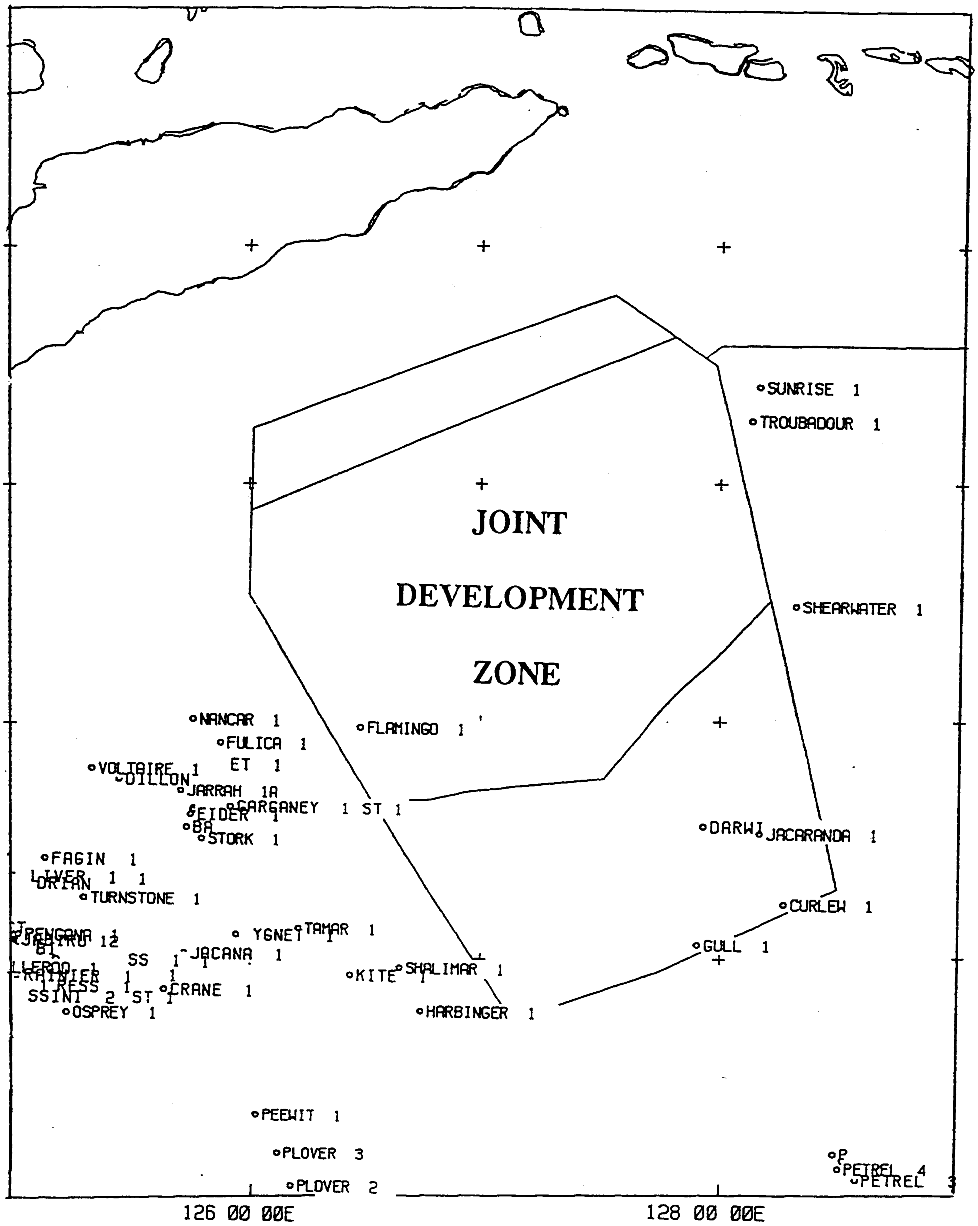

FIGURE 1: Location of the Joint Development Zone and adjacent areas showing the location of the wells drilled in the area.

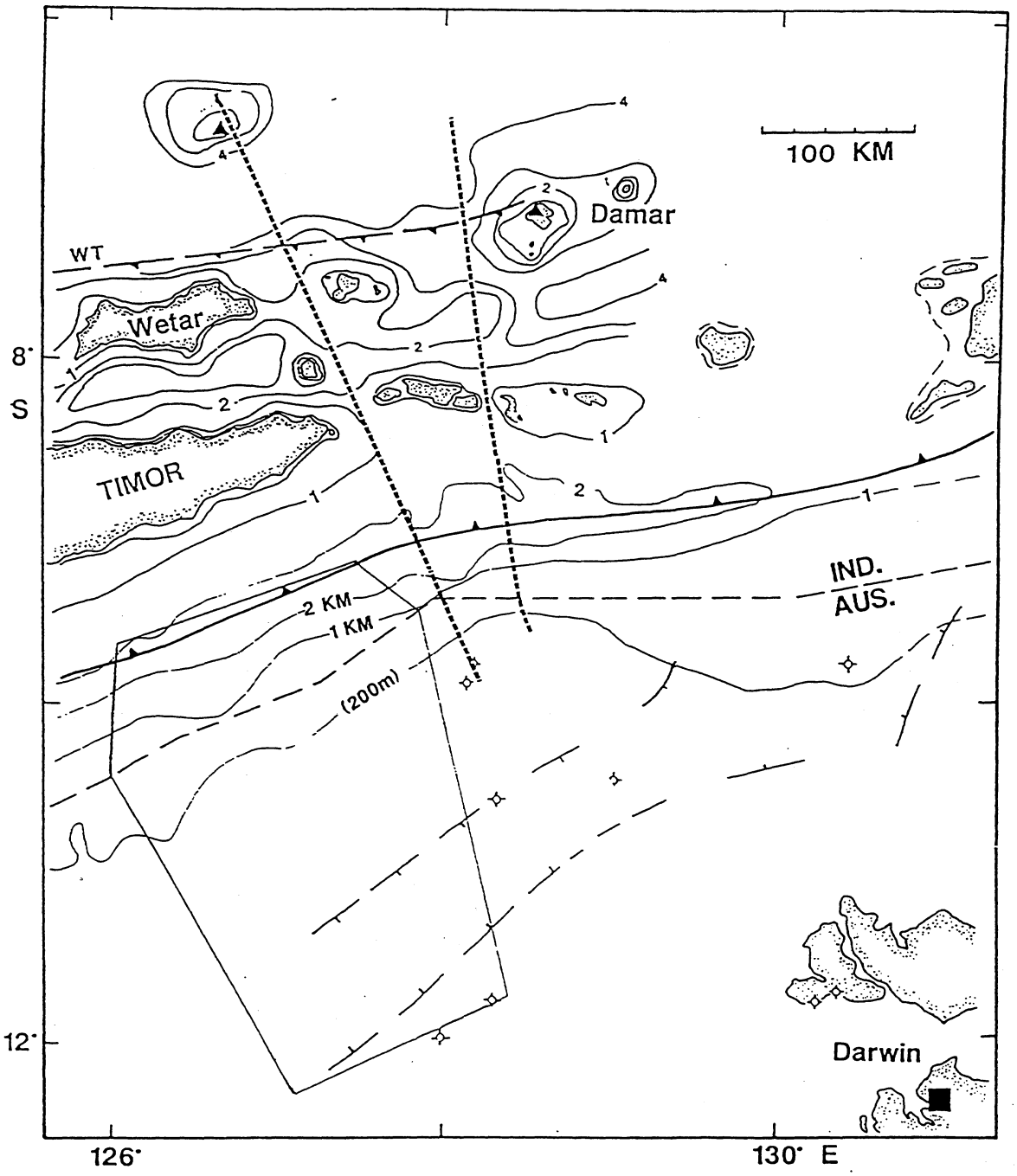

FIGURE 2: Map showing the approximate location of of the deep crustal lines shot across the Banda Arc by BIRPS in 1992.

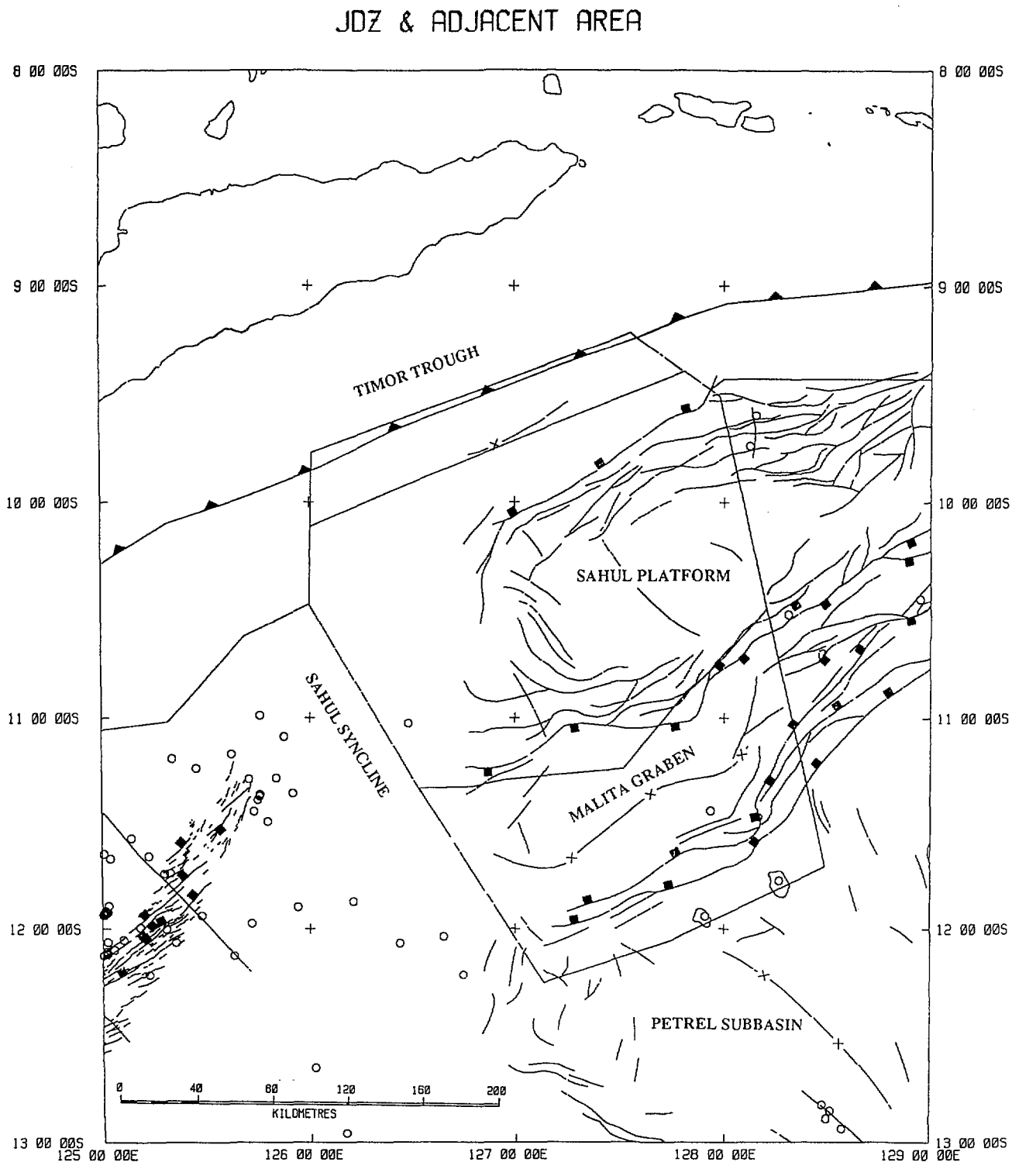

FIGURE 3: Structural framework map of the JDZ and adjacent regions

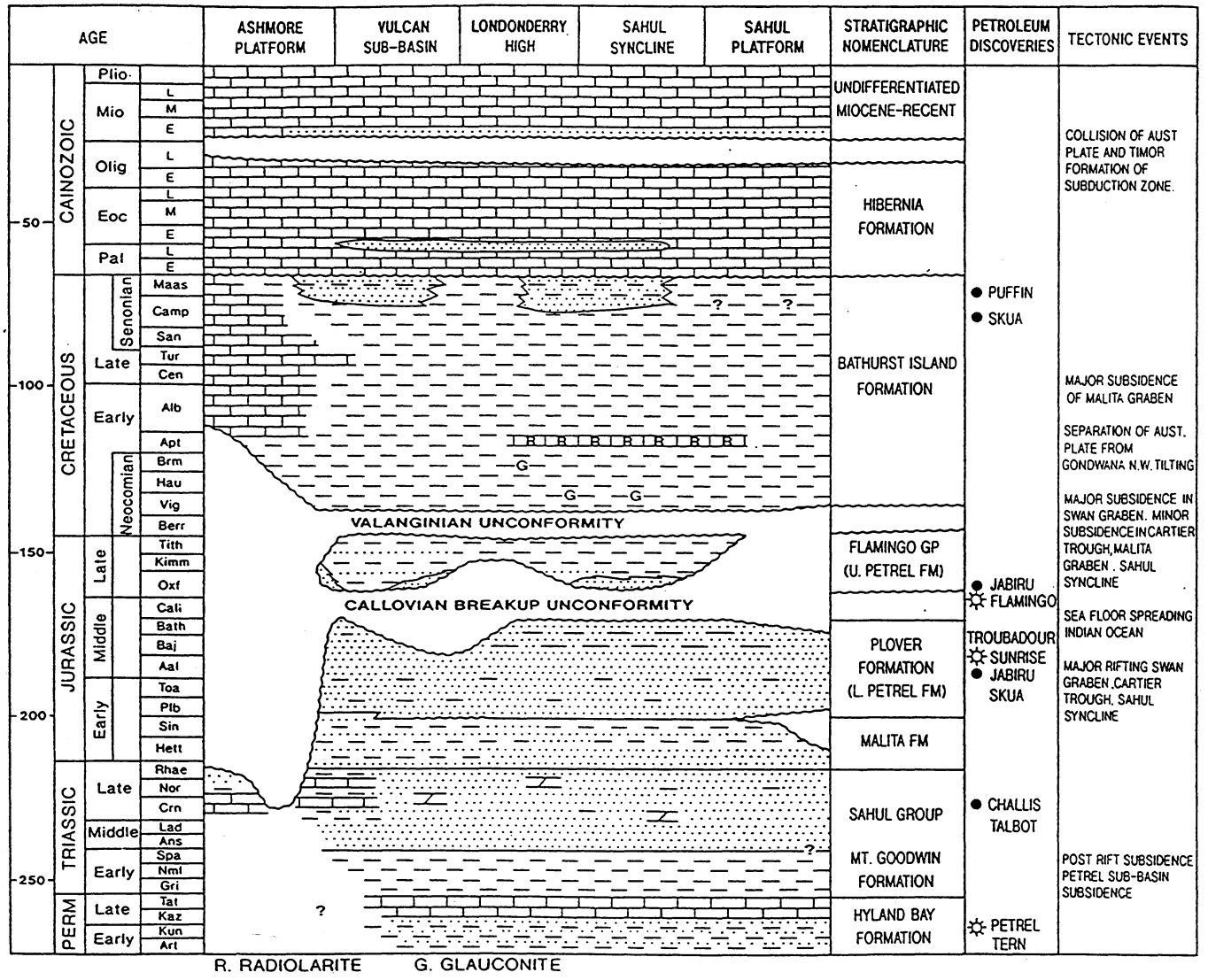

FIGURE 4: Stratigraphic column for the JDZ and adjacent regions (from Botten and Wulf, 1990)

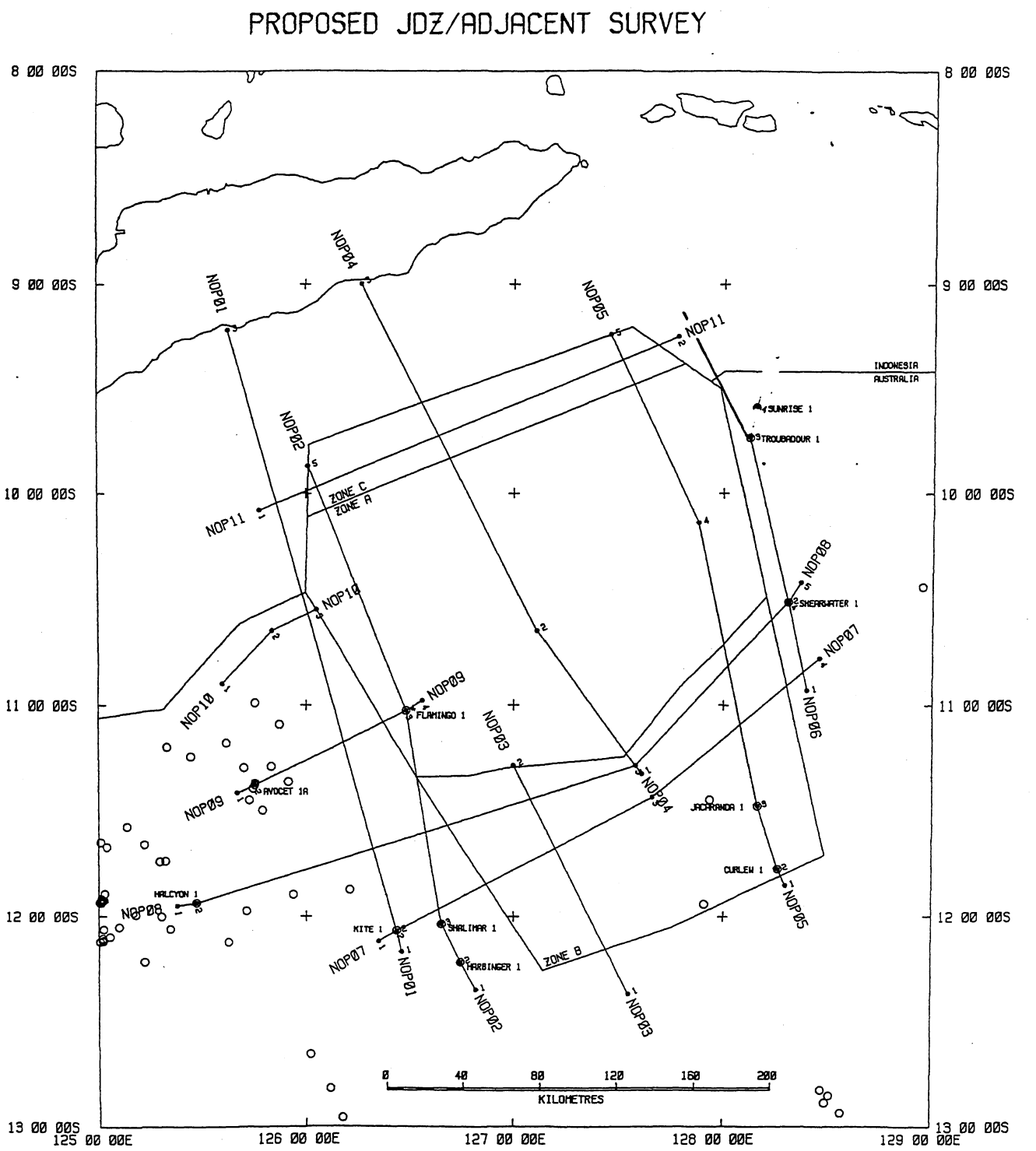

FIGURE 5: Track map of the JDZ and adjacent regions showing proposed lines.

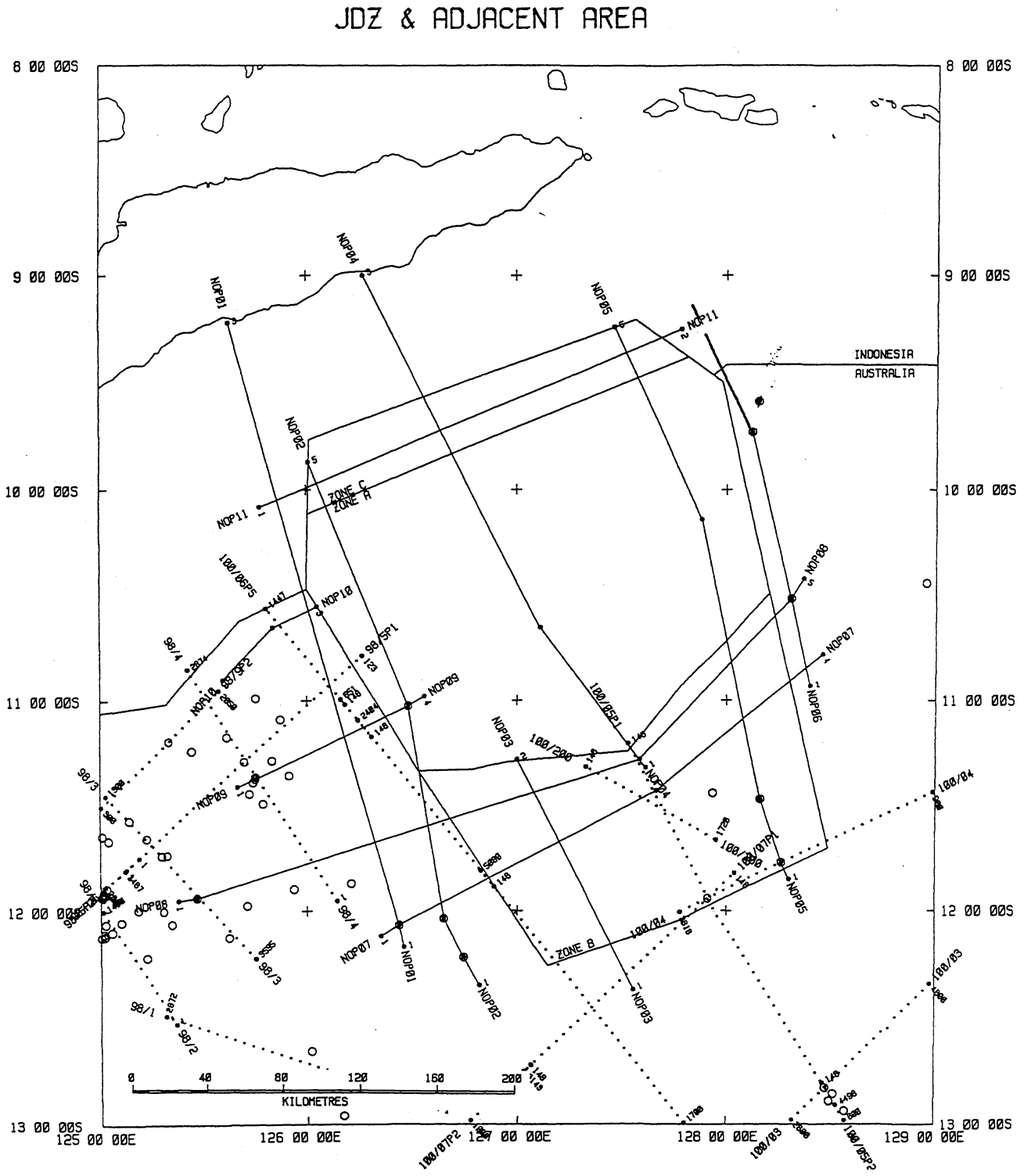

FIGURE 6. Track map showing the proposed lines for the JDZ and adjacent areas in relation to BMR surveys 98 and 100.

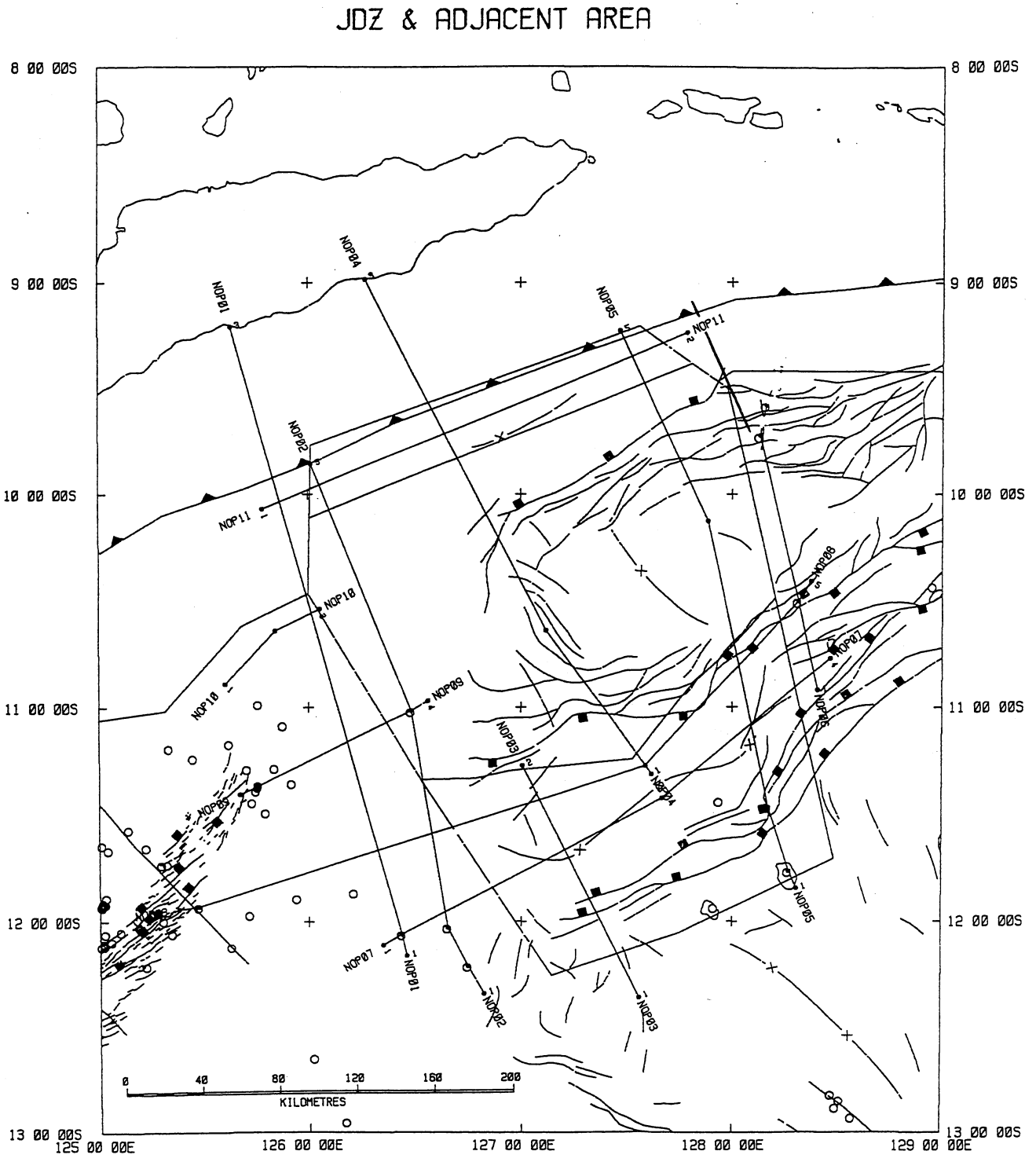

Figure 7. Regional structural elements with proposed tracks superimposed.