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Preliminary Post-cruise Report : BMR Survey 91

RV RIG SEISMIC INVESTIGATION OF THE OFFSHORE MARYBOROUGH BASIN, SOUTHERN QUEENSLAND CONTINENTAL MARGIN AND NORTHERN TASMAN BASIN - STRUCTURE, STRATIGRAPHY AND PETROLEUM RESOURCE POTENTIAL

Project 121.21
BMR Offshore Sedimentary Basins Sub-program

Co-chief Scientists P.J. Hill & C.J. Pigram

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Division of Marine Geosciences & Petroleum Geology

BMR Record 1990/69

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39. Seismic monitor record of diapiric structures in the deep-water Capricorn Basin (Line 91/030).

SUMMARY

The 'Maryborough' research cruise, BMR Survey 91, was successfully completed aboard RV Rig Seismic off the east Australian coast during the 30-day period 17 November to 16 December 1989. This geophysical and geological investigation resulted in the acquisition of new high-quality multichannel seismic reflection (MCS) data and other data over the offshore Maryborough Basin and adjacent basins along the SE Queensland continental margin. The main purpose of the work was to establish the structural and stratigraphic framework of these basins, study their evolution and assess petroleum potential.

The Maryborough Basin sequence includes sediments and volcanics of Late Triassic - Early Cretaceous age. The prospective Early Cretacous sedimentary section alone is known to attain a thickness of about 5 km. Deformation in the Late Cretaceous produced folding and high-angle faults. Our MCS survey of the offshore Maryborough Basin is the first survey of its kind using modern acquisition techniques since the last industry data were shot in 1970. As part of the Maryborough investigation, the wide continental shelf between Fraser Island and Moreton Bay was mapped to delineate a possible extension of the Maryborough Basin in this area. Aeromagnetic surveys flown by BMR during 1986-87 suggest that basin development continues out onto the shelf SE of Fraser Island.

Lines were also surveyed at the northern end of the Tasman Basin and across the Capricorn Basin to (i) provide stratigraphic control by seismic ties to the only deep offshore exploration wells in the region, Capricorn-1A and Aquarius-1, and (ii) collect the first high-quality, deep penetration MCS data in this area for the study of crustal structure, tectonic evolution and basin development.

A total of 2923 km of high quality MCS data was acquired along 31 lines. The 24-fold data were recorded at a ships speed of 5 kts using a 2400-m 96-channel streamer and dual tuned airgun array source (52 litre capacity). Record length was 12 seconds to allow definition of deep structure. In addition, a total of 10 sonobuoy refraction and wide-angle reflection experiments were successfully completed along selected parts of the seismic lines to assist interpretation of crustal structure. Sonobuoys were successfully deployed on the continental shelf SE of Fraser Island, in Hervey Bay, over the northern Tasman Basin and over the central Capricorn Basin.

Gravity and bathymetric data were collected along all lines in the study area - coverage amounted to about 3600 line-km. The magnetometer was deployed along all parts of seismic lines, except those in shallow water close inshore and within Hervey Bay. These shallow-water areas already have adequate recent BMR aeromagnetic survey coverage. 2450 line-km of magnetic profile data were acquired during the cruise.

A limited sampling program resulted in the recovery of seafloor samples from two dredge stations on the continental shelf and slope SE of Fraser Island.

Analysis of the shipboard data and some preliminary processed data indicates that: -
(i) a 5-km deep synclinal trough of faulted Early Cretaceous sediments of the Maryborough Basin underlies the western side of Hervey Bay,

(ii) the continental shelf SE of Fraser Island is underlain by well-stratified prograding Tertiary sequences up to 1.5 km thick, unconformably overlying late Palaeozoic - Early Cretaceous rocks with high seismic velocity (~3800-5000 m/s) and mainly relatively subdued magnetic expression,
(iii) a section about 2.0 s twt thick of Early Cretaceous Maryborough Formation / Burrum Coal Measures appears to be present SE of Fraser Island in the Wide Bay area,
(iv) the foot of the continental slope SE of Fraser Island and the extreme northern end of the Tasman Basin are underlain by a thick pile (~3 s twt) of post-breakup sediments, and
(v) large diapiric structures which probably represent late Cainozoic volcanics were recorded in the 2-km thick sedimentary section of the SE Capricorn Basin.

Post-cruise processing of the non-seismic (navigation, bathymetry and geopotential) and MCS data is expected to be finalized by the end of 1990.

INTRODUCTION

This is a preliminary post-cruise report for the RV Rig Seismic 'Maryborough' geophysical and geological research cruise that was successfully completed off southern Queensland during the 4-week period 17 November to 16 December 1989. Data acquisition by this cruise, BMR Survey 91, included multichannel reflection seismic (MCS), sonobuoy refraction, bathymetry, gravity and magnetics; some dredge sampling was also done. This report provides background information on the project, details of shipboard operations and data acquisition, plus some preliminary results of the investigation.

The general aim of the cruise was to, (i) investigate the extent and petroleum prospectivity of the offshore Maryborough Basin and its extension onto the south-east Queensland continental shelf, (ii) define its relation to the adjacent northern Tasman Basin and Kenn Plateau conjugate margin, (iii) tie the stratigraphy of the Maryborough Basin area to exploration wells in the Capricorn Basin, and (iv) improve our understanding of the structural style and petroleum potential of the deep-water Capricorn Basin.

The Maryborough Basin, located on the southern Queensland margin (Figs. 1 & 2), is a deep trough of Late Triassic - Early Cretaceous sediments and some volcanics. It is reputed to contain the greatest known thickness of Mesozoic sediments in Australia (Siller, 1961). At least two-thirds of the basin lies offshore. The most recent marine seismic survey in Hervey Bay took place in 1970. Interpretation of the seismic data indicates an Early Cretaceous section about 5 km thick. The offshore part of the basin has not been tested by drilling, and only limited exploration drilling has been done onshore. Nevertheless, shows of oil and gas have been recorded in some of the onshore wells, including a significant gas flow in Gregory River 1 well. A possible extension of the Maryborough Basin may exist on the continental shelf to the south-east of Fraser Island. The proximity of major hydrocarbon markets (eg. Brisbane and Gladstone) enhances the petroleum prospectivity of the basin. Relatively small gas discoveries could be commercially viable.

The northern Tasman Basin, Capricorn Basin, southern Queensland margin and conjugate Kenn Plateau (Fig. 1) are features that evolved through rifting of Tasman Fold Belt continental crust, and subsequent oblique opening of the Tasman Sea that began in the Late Cretaceous (~80 Ma) and ended in the early Tertiary (~60 Ma). This area of the east Australian margin remains relatively unexplored despite the known occurrence of thick sedimentary deposits and the suggestion of at least fair prospectivity. No investigations using modern multichannel seismic acquisition techniques have been undertaken; the last multichannel reflection survey was a reconnaissance investigation conducted in 1974 (Shell Development, 1977).

The southern Queensland margin/ northern Tasman Basin area lies on a sector of the east Australian continental margin not previously covered by earlier RV Rig Seismic cruises. Areas to the north and south have been studied. The Survey 91 investigation of the SE Queensland margin complements earlier studies off North-east Australia, the Lord Howe Rise, the northern NSW shelf and the Gippsland margin.

During the cruise 2923 km of 96-channel (24-fold) seismic reflection data (Fig. 2, App. 1), 3600 km of bathymetry and gravity profile data and 2450 km of magnetic profile data were collected. Seismic ties were made into two exploration wells (Capricorn-1A and Aquarius-1) in the Capricorn Basin. Ten sonobuoy refraction/ wide-angle reflection experiments (Fig. 2, App.2) were completed. Seafloor samples were recovered at two dredge sites on the continental shelf and slope SE of Fraser Island.

Acknowledgements

The skill and professionalism of the master and crew of RV Rig Seismic contributed significantly to the success of the cruise. Their assistance and co-operation is gratefully acknowledged. The ship's company comprised:-

Master	:	Henry Foreman	
Mate	:	Peter Thacker	15 Nov. to 21 Nov.
		Victor Bhagwat	21 Nov. to completion
2nd Mate	:	Bill McKay	15 Nov. to 01 Dec.
		Peter Thacker	01 Dec. to completion
AB	:	Norman Luscombe	15 Nov. to completion
AB	:	Graham Pretsel	"
AB	:	Mike Pitcher	"
Chief Engineer	:	Jim Finnie	"
2nd Engineer	:	Dean Stewart	"
Electrician	:	Peter Jiear	"
Engine Room Artificer	:	Don Brown	"
Chief Cook	:	Bill Fowler	"
Cook	:	Jeff Conerly	"
OS/Steward	:	Mark Cumner	"
Steward	:	Joe Caminitti	"

Staff of AUSLIG (Australian Surveying & Land Information Group) who positioned and operated the onshore HiFix radio-navigation stations are also thanked, as are the BMR officers involved in this work - Lindsay Miller and Peter Petkovic.

The shipboard work was carried out by a team of 21 scientists and technicians; they are is listed in Appendix 12.

OBJECTIVES

Survey 91 was the major data acquisition phase of the 'Maryborough' program, BMR project 121.21. The primary objectives of the research cruise were petroleum resource related; complementary studies of tectonic processes and regional stratigraphy also formed a component of the investigation.

The cruise objectives were -

1. To establish the structural and seismic stratigraphic framework of the offshore Maryborough Basin and investigate its petroleum prospectivity.

2. To investigate and map possible extensions of the Maryborough, or undiscovered basins, along the continental shelf between Fraser Island and Moreton Bay.

3. As an aid to evaluation of hydrocarbon potential and plays, to study the tectonic evolution of the Maryborough Basin, the

Cretaceous/early Tertiary rifting and seafloor spreading processes in the north Tasman Basin, and the inter-relationship of the Maryborough Basin/Capricorn Basin/north Tasman Basin tectonic development.

4. To improve our understanding of the structural style and petroleum potential of the deep-water Capricorn Basin by enhancing the present seismic data set through the collection of a series of high quality regional tie lines along and across the basin.

5. To tie the Maryborough Basin stratigraphy to the exploration wells in the Capricorn Basin.

6. To examine the structural style, stratigraphic development, and the deep crustal structure of the rift and transform margins of the northern Tasman Basin in relation to conceptual models of passive margin development, and associated hydrocarbon formation and accumulation.

Though the prime objective of the cruise was to map the extent, structure and stratigraphy of the Maryborough Basin, the study of margin development as an aid to predicting structure, stratigraphy and thermal history of basins in the region was an important part of the program. It was envisaged that the cruise would help to answer some questions fundamental to the understanding of regional tectonics and basin evolution. Such unanswered questions included :

What is the nature of the structural high (Bunker Ridge) forming the boundary between the Maryborough and Capricorn Basins?

How do the structural styles of the Maryborough and Capricorn Basins compare, and what is their relationship?

What is the crustal structure across the continental/oceanic transform margin at the northern end of the Tasman Basin?

How does the development of the transform zone relate to the evolution of the Capricorn Basin and southern Queensland / Kenn Plateau margins?

How do the conjugate margins (southern Queensland and Kenn Plateau) compare?

Are conceptual models (simple shear, pure shear) of margin and basin formation constrained by the deep seismic data?

How variable is oceanic crustal structure across the northern Tasman Basin - particularly in the vicinity of the relic spreading centre and toward the northern transform margin?

High quality, long record-length, multichannel seismic reflection data collected over the north Tasman Basin and its margins would allow the mapping of extensional and other structures deep in the crust and will provide an opportunity to test models of continental and oceanic rifting, continental separation and passive margin evolution (eg. Etheridge et al., 1988) - an understanding of these processes being fundamental to any evaluation of petroleum potential in the region.

The cruise attempted to address regional stratigraphic problems, so that a better assessment of prospectivity can be made, by the surveying of high quality regional seismic tie lines to link Capricorn Basin stratigraphy to that of the Tasman Basin, Kenn Plateau, southern Queensland margin and Maryborough Basin.

Figure 3 provides an overview of the proposed geoscience program prior to commencement of the cruise.

PRE-EXISTING DATA BASE

No multichannel seismic surveys using present industrial-standard acquisition techniques have been carried out in any of the areas investigated by this cruise. The most recent multichannel survey in the Hervey Bay area of the Maryborough Basin was in 1970 (Baxmann, 1971); reconnaissance seismic surveys of the southern Queensland margin and Capricorn Basin region were completed in 1973-74 (Gulf, 1974; Shell Development, 1977). There have been no seismic surveys (single or multichannel) over the Kenn Plateau area since the sparker survey (survey no. 13) of the BMR 1970-73 continental margins program.

Table 1 provides a summary of all previous offshore geophysical exploration activities in the Maryborough / Capricorn Basins area.

Maryborough Basin - Hervey Bay area

The pre-existing network of seismic lines is depicted in Figure 4. The pre-1969 data (Bruce, 1964; Smith, 1965) are of poor quality because of the techniques used (dynamite/single-4 fold coverage). A considerable improvement in data quality was achieved during surveys in 1969 (Tiger, 1969) and 1970 (Baxmann, 1971) using a 2400 m (active section) streamer and airgun array. 737 km of 24-fold seismic reflection data were recorded.

Early gravity work in the area included a NE-SW gravity traverse across Hervey Bay in 1958-59 (Dooley, 1959). Shell made gravity observations on Fraser Island and the mainland in 1973. These data are supplemented by the BMR regional network of stations (about 10 km spacing).

The 1964 Swain Reefs aeromagnetic survey by Gulf Oil (Affleck & Landau, 1965) covered the offshore area to the north of Fraser Island, and superseded previous aeromagnetic work over this region. Aeromagnetic surveys recently flown by BMR in 1986-87 have extended detailed coverage over the Maryborough Basin to the south of the Gulf Oil data. The BMR surveys were flown at an altitude of 150 m above ground level, with 1.5 km line spacing, and provide an important new data source for interpreting the geological structure of the region.

Between 1978 and 1980, the Queensland Department of Mines carried out a program of stratigraphic drilling in the Maryborough Basin; both deep (400^{+} m) and shallow holes were drilled (Cranfield, 1982). As part of this program, a 539-m deep stratigraphic hole (GSQ Sandy Cape 1-3R, Fig. 2) was drilled on the northern tip of Fraser Island (Grimes, 1982; Palmieri, 1984). This hole, which effectively sampled the outer continental shelf, passed through 420 m of Late Tertiary and Quaternary sandy marine shelf deposits, 172 m of mid-Tertiary interbedded basaltic volcanics and marine/deltaic/fluvial sediments, and penetrated 31 m of indurated sandstones and shales tentatively correlated with the Tiaro Coal Measures of the Maryborough Basin.

Southern Queensland shelf, Fraser Island-Moreton Bay

The main data set for this area comprises surveys 12, 13 and 15 of BMR's 1970-73 continental margins program (Fig. 5; Symonds, 1973). Sparker seismic, gravity, magnetics and bathymetry data were collected. The seismic data quality is poor-fair on the shelf and penetration is limited by the relatively low power of the sparker source.

The multichannel airgun seismic reconnaissance lines shot by Shell in 1973-74 (Shell Development, 1977) provide valuable but scant coverage (Fig. 6). Not all lines have been fully processed. BMR's 1986-87 aeromagnetic surveys extend only about 10-30 km onto the shelf.

A geological survey of the continental shelf and upper continental slope was carried out by BMR in 1970 (Marshall, 1977 & 1980). Bedrock samples were dredged from the upper slope off the northern end of Fraser I. These samples comprised calcilutite (from 512 m depth) and oligomictic conglomerate (from 293 m depth), the former being of late Miocene / early Pliocene age and the latter dated as possible Pliocene.

Northern Tasman Basin, Kenn Plateau and Capricorn Basin

Broad regional geophysical control is provided by surveys 12, 13, 14 and 15 of the BMR 1970-73 continental margins program (Fig. 5; Symonds, 1973; Mutter, 1974). Few other data are available for these areas - except for the northern end of the Capricorn Basin where an extensive grid of seismic lines was surveyed (Fig. 7 - Wilson, 1967; McAvoy & Temple, 1978). These lines were shot prior to the drilling in 1967 and 1968 of two exploratory wells, Capricorn-1A and Aquarius-1 (App. 10), both of which proved to be dry holes. The only multichannel surveys undertaken in the Capricorn Basin since then have been the 1973-74 reconnaissance surveys by Gulf (1974) and Shell Development (1977).

GEOLOGICAL AND GEOPHYSICAL BACKGROUND

Physiography of the northern Tasman Basin area

The northern end of the Tasman Basin is 200 - 300 km wide and lies at abyssal depths of 4200 - 4600 m (Fig. 3). The north-trending Tasmantid chain of guyots and seamounts forms a series of topographic highs along the centre of the basin that rise 1500 - 3000 m above the basin floor. Kenn Plateau, which forms the eastern margin of the basin, rises relatively steeply from the basin floor to depths of about 2000 m. The western (southern Queensland) margin consists of a 20 - 80 km wide shelf and steep slope, which often has a convex profile (Symonds, 1973).

The southern Queensland continental slope has an average slope of 4^{o} - 8^{o}, but can be as steep as 20^{o} in places. The steep slopes are thought to be due to rifting and canyon development. Canyon systems dissect the continental slope from just north of Fraser Island to the Moreton Island / Stradbroke Island area. Numerous small canyons running parallel to the slope may have formed by strong contour currents (Symonds, 1973). Submarine canyons are present on the continental slope off Fraser Island at about 25^{o} 30' S and 25^{o} 50' S (Marshall, 1972).

The narrowness of the shelf near 25^{o}S is the result of the outbuilding of sand across the old continental shelf to form Fraser Island (Marshall, 1977). Hervey Bay, on the western side Fraser Island, is a shallow (< 40 m deep) coastal embayment with sandy bottom; an ancient incised subaerial drainage system extends from the bay to the continental slope.

The Capricorn Channel is a large embayment located between the Swain Reefs and the reefs of the Capricorn and Bunker Groups. It generally slopes gently to the Tasman abyssal plain; there are slight increases in gradient between about 120 - 200 m and depths greater than 600 m. The NE - striking morpho-structural lineament coinciding with the southern extremity of the Capricorn Channel (or northern end of the Tasman Basin) and the southern end of Cato Trough (escarpment just NW of Cato I.) is thought to be the product of transform faulting associated with opening of the Tasman and Coral Seas (see next section).

<u>Tectonic development</u>

The geological evolution of the east Australian margin region has been dominated since late Mesozoic time by the continental rifting and seafloor spreading tectonic episodes which led to the formation of the Tasman Basin and Cato Trough. The magnetic anomaly pattern in the Tasman Sea indicates that seafloor spreading was active between chrons 33-24, about 80-60 Ma (Hayes & Ringis, 1973; Weissel & Hayes, 1977; Shaw, 1978 & 1979).

Models advanced for the development of Australian continental margins (Falvey, 1974; Falvey & Mutter, 1981) suggest that three main tectonic phases should be recognisable - (i) a Cretaceous rift valley phase of thermal uplift, followed by aerial rifting and continental deposition, (ii) Late Cretaceous-Palaeocene breakup with new oceanic crust being created, and (iii) a post breakup phase of slow subsidence (sag), marine transgression and deposition of prograding sediments across the shelf (Grimes et al., 1984).

Recent models of passive margin development invoking extension by detachment faulting and crustal underplating (Fig. 8; Lister et al., 1986; Etheridge et al., 1988; Lister & Etheridge, 1989; Etheridge et al., 1989) may be applicable to the conjugate southern Queensland/Kenn Plateau margins, at least on the basis of asymmetric margin morphology. Different models for the opening of the Tasman Sea have significant implications on possible mechanisms for the evolution of the north Tasman Sea and margins. For example, in the reconstruction of Weissel & Hayes (1977), extensive early opening is implied (Fig. 9) suggesting that Kenn Plateau may be oceanic or that it experienced a considerable degree of crustal extension. On the other hand, Shaw (1978) with his determination of more southerly (with age) finite poles infers that prior to chron 30 proto-Kenn Plateau remained attached to Australia and that early opening in the southern Tasman Sea was accommodated by large-scale strike-slip movement along the south-east of edge of the proto-plateau (Fig. 10). Data from this cruise may help to resolve such inconsistencies in tectonic models.

<u>Basin development</u>

Maryborough Basin

The Maryborough Basin (Figs. 1 & 2) is a Late Triassic - Early Cretaceous depositional area covering about 24600 km^2, of which about two-thirds is known to be located offshore (Siller, 1961; Ellis, 1966 & 1976, Cranfield, 1982 & 1989). There are no exposures of the

Maryborough Basin on Fraser Island apart from one small outcrop on the central west coast of the island (Grimes et al., 1987). The basin was deformed in the Late Cretaceous. The resultant folding varies in intensity. A series of broad, open folds with NW trending axes occurs north of Maryborough. Deformation was more intense to the south, and produced tight to isoclinal folds, faults, and steep dips in the coastal region (Murray, 1977).

Stratigraphy (based on above references) :-

			Thickness (m)
Tertiary	'Volcanics'	Isolated basalt remnants	-
"	Elliott Formation (c)	Sands and clays	52 (max.)
E.Cretaceous	Burrum Coal Measures (c)	Sandstone, shale, coal seams	1700-3000
"	Maryborough Formation (m)	Shale, sandstone, minor limestone	2150 (av.)
"	Grahams Creek Formation	Tuffs, lavas, sandstone, shale	1220(approx.)
E.Jurassic	Tiaro Coal Measures (c)	Shales, sandstones, coal	1370 (min.)
L.Triassic -E.Jurassic	Myrtle Creek Sandstone(c)	Sandstone, minor shale	455 (max.)

(c) continental
(m) marine

Typical lithostratigraphic relationships in the Maryborough Basin are seen in logs of LSD-1 Cherwell and LSD-2 Susan River exploration wells (Fig. 11).

The Late Triassic-Early Jurassic Myrtle Creek Sandstone has reservoir potential, while the overlying Tiaro Coal Measures is a possible source formation. However, the Grahams Creek Formation has generally been regarded as economic basement, and it is the overlying Early Cretaceous Maryborough Formation which has greatest petroleum prospects. It contains source rocks and some sandstone members of the formation have reservoir potential; structural closures and minor stratigraphic traps are present. Onshore well SDA Gregory River 1 (Shell Development, 1967) produced a significant gas flow from the 'lower sandy member' of the Maryborough Formation (Fig. 12). Though containing source material, the Burrum Coal Measures appear to lack suitable reservoir rocks. The Maryborough Basin is considered to be gas prone (Geological Survey of Queensland, 1981).

Offshore in the Hervey Bay area, seismic data indicate a large, faulted syncline of Early Cretaceous sediments blanketed by a flat-lying Tertiary cover about 500 m thick (Figs. 12 & 13). The eastern flank of the syncline is cut by an east-dipping fault with about 1300 m displacement. The faulting does not affect the Tertiary section, and so is probably of Late Cretaceous age, and may be related to the rift phase of tectonism preceding the opening of the Tasman Sea. Seismic basement - probably the largely volcanic Grahams Creek Formation, lies at a depth of almost 3s twt (about 5 km). Some deeper reflection events have been recorded (Baxmann, 1971), though these could not be tied to the onshore data. The 'basement' high of the Bunker Ridge (Fig. 14) is considered to represent the boundary between the Maryborough and Capricorn Basin located to the north-east, even though the Grahams Creek Formation probably underlies much of the Capricorn Basin (Fig. 15).

Aeromagnetic maps of the region (Figs. 16 & 17) clearly define the deep sedimentary trough of the NW-trending Maryborough Basin. Though it is uncertain whether a satisfactory seismic tie can be achieved between the Capricorn and Maryborough Basin over the Bunker Ridge, a possible line location was selected (Fig. 17) on the basis of the aeromagnetic data. Magnetic basement of the ridge beneath the line has been interpreted to lie at a depth of about 3660 m (Affleck & Landau, 1965).

Extension of the Maryborough Basin to the SE :

The aeromagnetic contours (Fig. 16) indicate that the Maryborough Basin extends out onto the continental shelf to the south-east. The limited offshore coverage of the aeromagnetics does not allow the basin to be traced very far onto the shelf. The BMR marine magnetic and gravity profiles (Figs. 18 & 19) are of some help, however. Apart from some large individual anomalies - possibly produced by Tertiary basalts - the magnetic profiles are fairly smooth to the south-east of the southern tip of Fraser Island, suggesting that the basin might in fact extend right across the shelf. The gravity data tend to support this deduction, though not unequivocally. The expected gravity low over the basin extension is not of large amplitude, perhaps not surprising since the gravity expression of the Maryborough Basin as a whole is relatively subdued considering the substantial thickness of sedimentary section it contains. Relatively high sediment density probably accounts for the subdued expression.

The available seismic data over the shelf are mainly of poor quality. The profiles across the shelf show a prominent shallow unconformity overlain by a thin wedge of ?Tertiary sediments which thickens toward the shelf edge. The Tertiary sediment wedge is seen to be at least several hundred metres thick. A narrow depocentre of presumed Late Cretaceous/Tertiary sediments (post-dating opening of the Tasman Sea) of significant thickness (1-2 s twt) extends along the continental rise (Fig. 14; Shell Development, 1977). Marine geophysical surveys of the 1970-73 continental margins program cover the offshore area, and examination of these data reveals at least limited basin development. The sparker seismic records of this old data set are only of poor-fair quality and show little penetration due to the low energy source. These data show at least 0.7 s, possibly 1.5 s, of section to the south-east of Fraser Island.

Capricorn Basin

The Capricorn Basin (Figs. 1 & 3) occupies a north-west trending zone of subsidence 150 km wide and over 300 km long, bounded by the Bunker Ridge to the west and the Swain Reefs High to the east. The Tasman Basin adjoins to the south. The Capricorn Basin contains a sequence of late Mesozoic and Tertiary marine (Neogene) and non-marine (Palaeogene) sediments 3000 m thick (Fig. 3; Ericson, 1976; Benbow, 1980). Normal tensional faulting near the basin axis and associated subsidence by late Mesozoic appears to have been part of the rift phase preceding breakup along the east Australian continental margin. Graben development in the Narrows area near Gladstone during the Palaeocene - middle Oligocene resulted in the deposition of a 300^+ m thick terrestrial section of oil shales (Swarbrick, 1976).

Deep exploration wells, Capricorn-1A and Aquarius-1 (App. 10; Carlsen & Wilson, 1968 a & b) located at the north-west end of the basin provide useful stratigraphic control in the region (Fig. 15). Capricorn-1A reached a total depth of 1710 m in equivalents of the Early Cretaceous Grahams Creek Formation, while Aquarius-1 drilled 40 km to the north-east penetrated basement of Palaeozoic rocks at total depth of 2658 m.

Kenn Plateau

This feature lies mainly at depths of 1000-3000 m, and is thought to represent a submerged and dissected fragment of the Tasman Fold Belt separated from Australia by Late Cretaceous/early Tertiary opening of the Tasman and Coral Seas. Sparker seismic data from the plateau area suggest that a rift-valley sequence at least 2000 m thick underlies a post-breakup sequence of maximum 1000 m thickness (Fig. 20; Willcox, 1981). Areas of thick sediment are also indicated by gravity lows.

CRUISE PLAN

The proposed program called for 28 days of geophysical / geological survey work, scheduled to begin in November 1989, with the ship sailing from Sydney and completing the cruise in Brisbane. The cruise would focus on the southern Queensland continental margin and the offshore Maryborough Basin. Survey lines extending north to the Capricorn Basin, and east across the northern Tasman Basin to Kenn Plateau, were important but of lower priority. The pre-cruise planned tracklines are indicated in Figure 3.

Up to 3150 km of seismic data were to be collected (Fig. 3) - involving a minimum of 14.5 days along-line shooting. A 2400 m (active section) streamer was to be used, possibly converting to a shorter 1200 m (active section) streamer to complete those lines in Hervey Bay which lie in relatively shallow water (approx. 10 - 15 m depth). The shorter streamer would allow greater manoeuvreability in case possible hazards such as uncharted sandbanks and pleasure craft had to be avoided.

In addition to acquisition of seismic reflection data, a number of sonobuoys would be deployed at suitable locations to provide information on crustal structure and velocities at depth. Gravity and 3.5/12 kHz echo sounder data were to be recorded continuously during the entire cruise, while the magnetometer would be deployed on all lines except those in Hervey Bay because of the water depth problem.

About 2 days were set aside towards the end of the cruise for a geological sampling program on the continental shelf and slope east of Fraser Island. The progam, to provide information on lithostratigraphy and hydrocarbon potential, would involve dredging and/or piston coring of exposures in fault scarps and canyon walls on the slope. Target definition would be largely on the basis of the new seismic data.

Seismic ties to Aquarius-1 and Capricorn-1A wells

These well sites are located within the boundaries of the Great Barrier Reef Marine Park (Fig. 21), but were drilled before the GBRMP was gazetted. They are the nearest suitable offshore wells which might allow useful stratigraphic control in other parts of the Capricorn Basin, the Maryborough Basin and northern Tasman Basin area. A research permit (no. G89/497), to allow the seismic tie lines to be run, was obtained from the GBR Marine Park Authority.

Survey in Hervey Bay

Hervey Bay is a shallow water area with depths generally substantially less than 40 m. The Bay is located just south of the GBR Marine Park which extends northward of 24^{o} 30' latitude (Fig. 21).

During their annual migration along the east Australian coast, pods of humpback whales congregate in Hervey Bay. This has developed into a major tourist attraction with a number of tourist operators taking visitors out onto the bay to view the whales. The whale season in Hervey Bay runs from August to October, with a peak in September. The area would be clear of whales by early December when the survey in Hervey Bay was scheduled. No whales were sighted during the cruise.

Because of shallow water and shifting sandbanks, Hervey Bay poses hazards to ship navigation and survey equipment. In 1969, 230 km of seismic was shot in the bay using a 28-airgun array and 2700 m streamer (Operations Report by O.N. Serck in Tiger (1969)). Though the survey was successfully completed, lead was lost from the streamer by scraping over sandbanks - requiring periodic re-balancing of the cable.

To minimize potential danger to ship and equipment over the shallower parts of the survey area, reducing the seismic streamer length to 1200 m active and towing it and the airguns at 5-7 m depth was a possible option. However , during the actual survey it was decided to continue shooting with the 2400 m streamer (see next section). Deployment of the magnetometer would not be possible, and would be unnecessary because of adequate aeromagnetic coverage.

SURVEY 91 OPERATIONS

The ship left Sydney at mid-day on 17 November 1989. Seafloor sampling commenced on 19 November soon after the ship arrived in the survey area off southern Queensland. MCS data acquisition began on 22 November and continued until 14 December, after which the ship sailed back to Sydney - arriving on 16 December. The return port was to have been Brisbane. However, about half-way through the cruise notification was received from Canberra that it had been changed to Sydney. This meant that 2 days would be lost in transit time; an extra one day of survey time was granted and this partly compensated for the unexpected effective reduction to the planned program. A day-by-day account of the cruise is provided in the narrative (App. 10).

The extent of the Rig Seismic survey coverage is shown in the track map of Figure 22. Time-annotated 1:1 000 000 scale track maps of areas A, B, C and D (Figs. 23, 24, 25 & 26, respectively) provide greater detail.

Equipment and data acquisition parameters

The survey equipment used during the cruise is listed in Appendix 4. The seismic streamer configuration is shown in Appendix 5, while Appendix 6 summarizes the shooting and recording parameters. Channel allocations for the digital non-seismic data are given in Appendix 8.

Geophysical survey

The cruise resulted in the acquisition of 2923 line-km of high quality multichannel seismic reflection data along 31 seismic lines (Figs. 2, 27 & 28). The 24-fold data were recorded at a ships speed of 5 kts using a 2400-m 96-channel streamer and dual tuned airgun array source (52 litre capacity). Record length was 12 seconds to allow definition of deep structure.

A total of 10 sonobuoy refraction and wide-angle reflection experiments were successfully completed along selected parts of the seismic lines (Fig. 2, App. 2).

Gravity and bathymetric data were collected along all lines in the study area - useful coverage amounted to about 3600 line-km. The magnetometer was deployed along all parts of seismic lines, except those in shallow water close inshore and within Hervey Bay. These shallow-water areas already have adequate recent BMR aeromagnetic survey coverage. Acquisition of 2450 line-km of high quality magnetic profile data (Fig. 29) was achieved during the cruise.

For the shallow-water work in Hervey Bay, the airgun depth was reduced to 5 m and the streamer adjusted to run at 5 m depth as well. An extra bird was added to the front of the active section and the amount of tow-leader out (and thereby neartrace offset) reduced. After successfully running the first line (91/015) into Hervey Bay with the 2400 m streamer, it was decided that conditions were safe to shoot the rest of the lines in the Bay with the long streamer length, rather than reducing it to 1200 m. Some relocation of the planned lines was necessary to avoid particularly shallow areas (< ~15 m) and to allow sufficient room to manoeuvre with the longer cable.

Geological sampling

Though basically a geophysical cruise, a short geological sampling program was conducted on the continental shelf and slope south-east of Fraser Island. The sampling was done at the start of the cruise, rather than at the end as initially intended, to allow additional time to prepare the seismic equipment, particularly the airgun arrays, for survey operations. Samples were recovered from 2 dredge stations. However, failure of one of the ship's three generators during the fourth dredge haul meant that the sampling program could not continue without risk of losing the wire on the main winch. The shaft generator normally on board was in Newcastle being overhauled. Operating the winch on the remaining two generators would have left no backup in the event of a further failure.

Details of the dredging results are provided below; locations of stations DR1, DR2 and DR3 are shown in Figure 28.

Station	Location	Co-ordinates	Water Depth (m)	Sample Recovered / Remarks
DR1	Southern Barwon Bank, eastern side	26° 34.4'S 153° 31.6 E	100-30	Haul 1: dredge lost Haul 2: carbonate-cemented quartz sand(stone), cobble-size fragment + smaller pieces
DR2	Northern Barwon Bank, eastern side	26° 30.0'S 153° 32.4'E	45-30	Dredge lost
DR3	Lower continental slope, E. of Barwon Bank	26° 32.5'S 154° 04.5'E	4000-3500	Green-grey calcareous mud, firm

A summary of geophysical/geological data collected during Survey 91 is provided Appendix 3.

GEOPHYSICAL EQUIPMENT - GENERAL COMMENTS ON PERFORMANCE

Most of the geophysical systems performed remarkably well, particularly considering that this was the first research cruise after a extensive re-fit of the ship. Because it had not been possible to adequately trial many of the modifications that had been made, Survey 91 effectively served as a shake-down cruise in addition to having the task of completing a full research program.

The most notable problem encountered, and one that continued to be of concern for much of the cruise, was the instability of the seismic acquisition system. Seismic acquisition was disrupted by intermittent system crashes. Despite much concerted effort to trace the cause of the problem, positive identification remained elusive. Surges in the ships power may have been responsible, affecting one or more of the peripheral devices. Towards the end of the cruise it appeared that the 6250 bpi Telex tape drives may have been the source of some of the crashes. Time lost in attempting to rectify the problem and in re-running parts of affected lines was the main reason that planned reconnaissance lines to Kenn Plateau had to be abandoned.

HiFix radio navigation was operated during the cruise to provide accurate positioning outside the GPS window and to allow a thorough evaluation of the modified BMR system under survey conditions. Shore station equipment failures, fractional lane jumps, erratic drift-rate changes and poor night-time reception meant that the HiFix was not always reliable for real-time navigation. Modification of the DAS software may make the HiFix system more useful for this purpose. Post-processing of the HiFix data at BMR is expected to produce industry-standard navigation for much of the survey when GPS coverage was not available.

SHIPBOARD SYSTEMS PERFORMANCE - DETAILS
(by Heather Miller)

Non-seismic systems

The non-seismic data acquisition system (DAS) ran for the duration of the cruise with 8 breaks in data collection. Four breaks were related to a problem with using the 6250 bpi tape drive to check seismic tapes and this will need to be investigated further. During day 323 the systems were intentionally powered down from 1651 to 1902 GMT after the ship's generators failed, to avoid any damage while the ship's power supply was stabilised. In total, 5 hours 4 minutes of non-seismic data were lost.

NAVIGATION

Positioning of the ship is derived from three independent systems; Navstar Global Positioning System (GPS), dead reckoning with updates from the U.S. Navy Navigation Satellite System (Transit satnavs), and radio navigation using Decca HiFix-6.

All ship positions are calculated in the WGS72 coordinate system (as used by the Transit satellites), except the on-board GPS receiver which has been calculating positions in the WGS84 coordinate system since January 1987. The difference between WGS72 and WGS84 is of the order of a metre so no conversions are performed.

Navstar Global Positioning System

The onboard Magnavox T-Set receiver using the GPS coarse/acquisition (C/A) code gives continuous absolute positioning within 35 metres rms under optimum conditions. At present the system is still in the experimental stage with only 10 of the proposed 18 satellites in functioning orbit. Limited satellite visibility results in GPS positioning being available for approximately 10 hours a day. This period could be extended to 13 hours in two satellite mode by using an atomic frequency standard. The success of two satellite mode depends entirely on an acceptable frequency bias between the atomic standard and the satellite transmissions being determined during the previous period of three and four satellite visibility.

Experimentation with the GPS receiver in the past has shown two satellite positioning to be unreliable. There have been many suggestions as to why this is and an attempt was again made to incorporate clock aiding at the beginning of this cruise, but with no success. It now appears that the signal from the frequency bias is not strong enough and a new cabling configuration will need to be set up. While attempting to incorporate clock-aiding the receiver had to be set to clock-aiding mode and therefore the system always attempted to clock-aid when two satellites were available, even though it is suspected that the receiver was not detecting the 5 MHz reference signal from the frequency standard. Thus any positioning derived from periods of two satellite visibility should be treated warily. During periods of three and four satellite visibility good positioning data were obtained.

During the transit to Sydney after survey completion, the cable from the atomic standard to the receiver was shortened and clock-aiding was again tried. Although first indications were good, further tests will need to be conducted to confirm that the problem has been solved.

Dead Reckoning Systems

Two independent systems incorporating a gyro compass, dual axis sonar-doppler and Transit satnav receiver provide basic dead reckoning for periods when the other navigation systems prove inadequate.

The primary dead reckoning system of SG Brown gyro, Magnavox MX610D sonar-doppler and MX1107RS dual channel satnav receiver provides one of the best available positioning systems of this type. A lower grade system of Robertson gyro, Raytheon DSN450 sonar-doppler and MX1142 single channel satnav receiver is used as a backup.

Both sonar-dopplers have problems in rough weather or when heading into the sea. Air trapped under the ship's hull combined with turbulence in the water flow along the hull can blank the transmissions of all sonar-doppler systems installed on the ship. This problem is inherent in the ship's design and the placement of the transducer banks for the sonar-dopplers. Before this survey the shafts of both sonar-dopplers were lengthened but no appreciable difference was noticed.

The sonar-dopplers provided an adequate back-up to the primary navigation systems except in deep water. In depths of 300 m the dead reckoning positions were up to 1 nmi out per hour and in strong currents off the shelf the positions were up to 3 nmi out per hour. Both sonar-dopplers were calibrated prior to this survey. From the navigation information collected in Hervey Bay it appears that they both may still require some further fine-tuning. The Magnavox sonar-doppler still appears to be misaligned enough to put the ship's position out by up to 0.4 nmi per hour.

HiFix

A Decca HiFix-6 radio navigation chain was operated for the entire cruise with middling results. BMR Marine has been experimenting for some time to extend the effective range of the HiFix system by operating it in circular mode with all stations slaved to their own rubidium standard. Such a system is affected by the individual drift of the rubidium standard.

The drift rate of the each station's rubidium standard affects the positioning data derived from the HiFix chain. In order to compensate for this effect each rubidium standard's drift rate is calculated by comparing observed HiFix ranges to theoretical ranges derived from the GPS data.

A second HiFix receiver was installed prior to this cruise allowing 5 stations to be received and monitored at any time. This worked well. However, HiFix reception and use for navigation was restricted by the efficiency of the on-shore equipment. A total of six transmitter sites (App. 7) were occupied. For the south Fraser Island portion of the survey transmitting stations were sited at Coolum Beach, Double Island Point and Fraser Island. Fraser Island and Coolum Beach provided good positioning, and drift rates were continually monitored and incorporated into the navigation system to provide drift compensation. Because of on-shore equipment problems at the Double Island Point site, the drift rate of this station was never stable and signal reception was very noisy and badly affected by lane jumps. For the Hervey Bay portion, the Coolum Beach equipment was re-sited to Pialba and the Double Island Point equipment moved to Bargara. A fourth station was erected at Agnes Waters

(Town of 1770). It was hoped to continue using the Fraser Island station while in Hervey Bay but reception was poor from the other side of the island. Poor equipment restricted the use of Agnes Waters and the equipment at Bargara still showed the same problems it had at Double Island Point. Therefore it was decided to slave Bargara off the Pialba station rather than continue to run with independent rubidium standards. This worked well and the only limiting factor was geometry between the ship and shore stations.

BATHYMETRY

Bathymetric data were obtained from two Raytheon echo-sounders, one 12 kHz and one 3.5 kHz and both with a maximum output of 2 kW. Little sub-bottom information was gained from the 3.5 kHz which was disappointing, but it provided a useful back-up to the depths from the 12 kHz.

GRAVITY

Gravity data were obtained using a Bodenseewerk KSS-31 Marine Gravity meter. The system failed once during the cruise when it caged and then on reinitialisation the sensor toppled. After being manually caged it gave no further problems. It was intentionally caged when the ship's generator failed and recovered with no problems. In the past an oscillation of approximately 1 mgal magnitude and a period of 4-5 minutes has been noticed when in harbour. Before this survey the meter was levelled twice and the oscillation did not appear before we sailed.

MAGNETICS

Magnetics data was collected throughout the survey except when the water depth was too shallow (as in Hervey Bay), using a Geometrics G801/803 marine proton precession magnetometer.

<u>Seismic system</u>

The seismic system was very unstable for most of the survey and the cause of the continual problems is still an unknown. It is suspected that the unstable ship's power may have been the initial culprit and began a virus of problems which spread into one or more peripheral devices. Certainly the 6250 bpi Telex tape drives were affected and as the survey continued their performance became more suspect. Despite system problems and crashes, shooting continued and 12 second records of 96 channels at a 2 ms sampling rate were collected. Data were collected, as far as possible, according to draft BMR guidelines (App. 9). The ESU designed IFP (instantaneous floating point) card was used in the Phoenix 6000 series high level analogue data acquisition system. This was designed to increase the dynamic range of the seismic system from 90 dB to 120 dB.

The seismic cable ran extremely well all survey, and the Syntron DCL-3 birds had little trouble maintaining the cable at the required depth.

The gun arrays both had an additional two guns added as spares prior to this survey, and consequently the gun controller was run with new software. The gun controller may have caused some of the initial problems with the seismic system until the temperature in the gun shack was lowered and stabilised somewhat.

PRELIMINARY RESULTS / COMMENTS

Some preliminary findings of the cruise, based mainly on the unprocessed shipboard data, are as follows.

- The Hervey Bay seismic monitor records outline a major NNW-trending synclinal structure in the Early Cretaceous Maryborough Basin formations; visible penetration is limited to about 1.4 s twt in the monitor records. A preliminary stack section (western part of line 91/021; Fig. 30) indicates a large, faulted syncline of Early Cretaceous sediments blanketed by a flat-lying Tertiary cover several hundred metres thick. The eastern flank of the syncline is cut by an east-dipping fault with large displacement. The Tertiary section is not affected by the faulting. The observed structures may be related to transtensional rifting preceding the opening of the Tasman Sea. A prominent lower horizon - probably near the top of the volcanic Grahams Creek Formation, lies at a depth of almost 3s twt (about 5 km).

- SE of Fraser Island, the Tertiary section on the continental shelf thickens towards the shelf edge and is underlain by a prominent unconformity. Well-stratified prograding sequences at the edge (Fig. 31) are up to 1.5 s twt thick. Structure and stratification beneath the unconformity is difficult to discern on the monitor records because of shallow water ringing/multiples. However, about 2.0 s twt of section appears to be present on inshore lines near Wide Bay where a SE extension of the Maryborough Basin is expected. Refraction data from shot records indicate velocities of 4000-5000 m/s for the sub-unconformity; velocity surveys in onshore Gregory River-1 well yielded a value of about 4200 m/s for the Maryborough Formation.

- The sonobuoy data from the shelf SE of Fraser Island, Hervey Bay and the central Capricorn Basin (Figs. 32-36) confirm that relatively high-velocity (3850-4920 m/s) strata are present at fairly shallow depth sub-bottom (generally at depths substantially less than about 2.5 km). These high velocity units may be Mesozoic rocks of the Maryborough Basin and/or late Palaeozoic - Triassic basement.

- Large areas of the continental shelf are magnetically quiet, implying a thick Mesozoic section or possibly (? relatively shallow) non-magnetic Palaeozoic basement.

- The bathymetry data indicate that the continental slope SE of Fraser Island is deeply incised by canyons. These offer excellent prospects for future sampling programs in this area. 12 kHz profiles along the outer continental shelf (Figs. 37 & 38) show that the heads of canyon systems are characterized by steep-walled incisions hundreds of metres deep and several kilometres across.

- The foot of the continental slope is underlain by a thick (~3 s twt) pile of post-breakup sediment.

- At least 3.0 s twt of sedimentary section is present in deep water at the extreme northern end of the Tasman Basin adjacent to the postulated NE-trending transform fault which forms the boundary between it and the Capricorn Basin to the north.

- Diapiric structures / buried mounds were recorded in the sedimentary section of the SE Capricorn Basin (Fig. 39). They occur in an area where the Capricorn Basin sequence is about 2 s twt thick. The structures have positive seafloor relief of about 200 m and are 1-2 km in diameter. They probably represent late Cainozoic volcanic buildups and intrusions.

CONCLUSIONS

Survey 91 by RV Rig Seismic resulted in the acquisition of a major new geoscientific data set over the offshore Maryborough Basin, the northern Tasman Basin and the deep-water Capricorn Basin. This data set will lead to a significantly improved understandng of the geological structure, stratigraphy, evolution and petroleum potential of this region.

The data collected included 2923 line-km of 24-fold, 12s record-length MCS data, 10 successful sonobuoy experiments, 3600 km of gravity and bathymetric data, and 2450 km of magnetic profiles.

Post-cruise processing of the non-seismic (navigation, bathymetry and geopotential) data is almost complete, while processing of the seismic data is well advanced. The complete set of final processed data is expected to be available by the end of 1990. A comprehensive analysis of the processed data is planned.

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APPENDIX 1. SEISMIC LINE DETAILS

Line	Start Time ddd.hhmm	Stop Time ddd.hhmm	Data Collected	Seismic Tapes	Length (km)
91/001	327.1118	327.1514\	24f,b,g	91/001-003,005-030	102
	328.0039	328.0827/			
91/002	328.1153	328.2231	24f,b,g,m	91/031-050	78
91/003	329.0442	329.1124	24f,b,g,m	91/051-068	62
91/004	329.1332	330.1023	24f,b,g,m	91/069-107	132
91/005	330.1729	331.2025	24f,b,g,m	91/108-157	147
91/006	332.0135	332.1614	24f,b,g,m	91/158-189	137
91/007	333.0008	333.1200	24f,b,g,m	91/190-218	111
91/008	333.1539	334.0030\	24f,b,g,m	91/219-249	126
	334.0142	334.0658/			
91/009	334.0730	334.1842	24f,b,g,m	91/250-273	100
91/010	334.2109	335.0513	24f,b,g,m	91/274-297	79
91/011	335.1042	335.1821	24f,b,g,m	91/298-315	74
91/012	335.2055	336.0747\	24f,b,g,m	91/316-343,345-374	225
	337.0143	337.0313|			
	337.0818	337.2054/			
91/013	338.0050	338.2028	24f,b,g,m	91/375-417	173
91/014	339.0251	339.0818	24f,b,g,m	91/418-431	50
91/015	339.1201	339.2309	24f,b,g,m	91/432-456	106
91/016	340.0401	340.0928	24f,b,g	91/457-469	49
91/017	340.0928	340.1244	24f,b,g	91/470-477	31
91/018	340.1440	340.1928	24f,b,g	91/478-487	44
91/019	341.0033	341.0455	24f,b,g	91/488-499	40
91/020	341.0605	341.1346	24f,b,g	91/500-516	71
91/021	341.2039	342.0515	24f,b,g	91/517-535	80
91/022	342.0651	342.1430	24f,b,g	91/536-552	71
91/023	342.1430	342.1839	24f,b,g	91/552-561	38
91/024	343.0035	343.0643	24f,b,g	91/562-575	57
91/025	343.0902	343.1634	24f,b,g,m	91/576-592	67
91/026	343.2303	344.1010	24f,b,g,m	91/593-615	96
91/027	344.1131	345.0454	24f,b,g,m	91/616-654	152
91/028	345.0714	345.1342	24f,b,g,m	91/655-668	59
91/029	345.1605	346.1644	24f,b,g,m	91/669-715	188
91/030	347.0005	347.0700	24f,b,g,m	91/716-731	64
91/031	347.0700	347.1829	24f,b,g,m	91/731-755	114

Total 2923 km

.... Times in GMT

.... 24f - 24-fold seismic data
b - bathymetric data
g - gravity data
m - magnetic data

APPENDIX 2. SONOBUOY EXPERIMENTS

No.	Line	Area	Time Deployed ddd.hhmm	End Recording ddd.hhmm	Seismic Tapes
1	91/004	Shelf, SE of Fraser I.	329.1348	329.1911	91/070-083
2	91/004	" " " "	330.0310	330.1032	91/090-107
3	91/005	" " " "	331.1132	331.1750	91/137-151
4	91/010	" " " "	334.2346	335.0519	91/282-297
5	91/011	" " " "	335.1155	335.1822	91/301-314
6	91/013	Northern Tasman Sea	338.0151	338.0617	91/378-387
7	91/019	Hervey Bay	341.0128	341.0510	91/490-499
8	91/020	" "	341.0741	341.1357	91/503-516
9	91/021	" "	341.2106	No good, replaced by SB 10	
10	91/021	" "	341.2141	342.0523	91/519-535
11	91/029	Capricorn Basin	346.0051	346.1003	91/688-707

.... Times in GMT

APPENDIX 3. SUMMARY OF SURVEY 91 DATA ACQUISITION, GEOPHYSICAL & GEOLOGICAL SAMPLING

Multichannel seismic reflection (24-fold):	2923 line-km
Sonobuoy seismic refraction experiments:	10
Magnetic profiles:	2450 line-km
Gravity profiles:	3600 line-km
Bathymetry profiles (3.5/12 kHz sounders):	3600 line-km
Sampling stations (dredge) with recovery:	2

APPENDIX 4. LIST OF EQUIPMENT

GEOPHYSICAL

Seismic System

Streamer
- 2400 m Teledyne hydrophone analogue streamer configured as 96 x 25 m groups
- 10 hydrophones per 12.5 m group
- ~15 microV noise; maximum ambient at 5 knots
- Syntron RCL-3 individually addressable cable levellers

Source array
- 52.4/73.4 litre (3200/4480 cubic inch), 28-element tuned Texas Instruments airgun array; 20 elements (3200 cubic inch) equally divided over two strings
- Teledyne gun signature phones, gun depth sensors, and I/O SS-8 shot sensors
- 4 x Price A-300 compressors, each rated at 300 scfm @ 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 range
  - 15 bit integer card
- 6250 bpi Telex tape drives
- data read after write in demultiplexed SEG-Y format
- 2 ms sampling with 96 channels
- streamer noise, leakage, and individual group QC
- source array timing QC
- recording oscillator and 4 seismic monitor QC

Seismic Refraction System

- Reftek sonobuoy receiver
- Reftek 2 sonobuoys
- Yaesu sonobuoy receiver

Bathymetric Systems

- Raytheon deep-sea echo-sounder; 2 kW maximum output at 3.5 kHz
- Raytheon deep-sea echo-sounder; 2 kW maximum output at 12 kHz

Magnetometer System

- 2 x Geometrics G-801/803 proton precession magnetometers; may be used as standard single-sensor cable or in horizontal gradiometer configuration
- Geometrics G-803 proton precession magnetometer; single sensor cable

Gravity Meter

- Bodenseewerk Geosystem KSS-31 marine gravity meter

Navigation Systems

GPS Navigation System
- Magnavox T-Set GPS navigator

Prime Transit System
- Magnavox MX-1107RS dual channel satellite receiver
- Magnavox MX-610D dual-axis sonar doppler speed log
- SG Brown gyro-compass

Secondary Transit System
- Magnavox MX-1142 single channel satellite receiver
- Raytheon DSN-450 dual-axis sonar doppler speed log
- Robertson gyro-compass

Radio Navigation
- Decca HiFix-6

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.

GEOLOGICAL

- deep-sea geological winch containing 10 km of 18 mm wire
- gravity and piston corers, maximum barrel length 10 m
- chain-bag and pipe dredges

APPENDIX 5. SEISMIC STREAMER CONFIGURATION

CRUISE : MARYBOROUGH - 91 DATE : 14 DEC '89

TOTAL ACTIVE LENGTH : 2400 m. Number of Chans = 96

CHAN #	SECTION	SERIAL #	LEADS kg	BIRDS	SECTION LENGTH (m)
	Tow Leader				Variable
	Stretch # 1	600			50
	Stretch # 2	S2			50
	DT# 1 WB# 1	583-014-003		B1	2
	Adaptor 8 > 4	187-188-4x25-01		B0	2
1-4	Active# 1	86/002	7x2.0		100
	Adaptor 8 > 4	—			2
5-8	Active# 2	83/104	2x1.0, 5x1.5		100
	Adaptor 16 > 8	—			2
	DT# 2 WB# 2	—		B2	2
9-12	Active# 3	84/021	1x1.0, 6x1.5		100
13-16	Active# 4	84/028	4x1.0, 1x1.5, 2x2.5		100
	Adaptor straight through	—		B3	2
	Adaptor 16 > 8	—			2
17-20	Active# 5	88/001	4x1.5, 2x2.0, 1x2.5		100
21-24	Active# 6	88/004	5x1.5, 1x2.0, 1x2.5		100
	WB #3	034		B4	2
	Adaptor 48 > 24	189-188-2502			2
25-28	Active# 7	84/101	4x1.5, 3x2.0		100
29-32	Active# 8	84/011	3x1.5, 2x2.0, 2x2.5		100
	Adaptor straight through	041		B5	2
33-36	Active# 9	88/010	5x1.5, 1x2.0, 1x2.5		100
37-40	Active# 10	88/007	6x1.5, 1x2.0		100
	DT# 3	009		B6	2
41-44	Active# 11	88/003	5x1.5, 2x2.0		100
45-48	Active# 12	—	2x1.0, 4x1.5		100
	DT# 4 WB# 4	020		B7	2
	Adaptor 48 > 24	188-??-03			2
49-52	Active# 13	103	4x1.5, 3x2.0		100
53-56	Active# 14	87/011	3x1.5, 3x2.0, 1x3.0		100
	DT# 5	032		B8	2
57-60	Active# 15	—	2x1.5, 5x2.0		100
61-64	Active# 16	1287-153-12	1x1.0, 2x1.5, 4x2.0		100
	DT# 6	014		B9	2
65-68	Active# 17	88-008	7x2.0		100
69-72	Active# 18	—	2x1.0, 3x1.5, 2x2.0		100
	DT# 7 WB# 5	001		B10	2
	Adaptor 48 > 24	189-188-25-01			2
73-76	Active# 19	88-006	2x1.0, 1x1.5, 3x2.0, 1x2.5		100
77-80	Active# 20	019	3x1.0, 3x1.5, 1x2.0		100
	DT# 8	017		B11	2
81-84	Active# 21	102	2x1.0, 4x1.5, 1x2.0		100
85-88	Active# 22	026	1x0.5, 4x1.5, 1x2.0, 1x2.5		100
	DT# 9	036		B12	2
89-92	Active# 23	87/001	2x1.0, 4x1.5		100
93-96	Active# 24	007	5x1.5, 1x2.0, 1x2.5		100
	DT# 10 WB# 6	028		B13	2
	2 Stretch #3 & 4	S4 012 / S3			50 + 50
	Tail Plug				1
	Tail Rope				300
	Tail Buoy (foam)				

Record every cable section
Record leads as n X wt. (e.g. 5 X 1, 7 X 1/2)
kg

APPENDIX 6. SHOOTING AND RECORDING PARAMETERS

Source:	2 x 1600 cubic inch airgun array
Shot spacing:	50 m
Shot interval:	19.4 seconds at 5 knots
Cable length:	2400 m active; ~3000 m to tail buoy
Group interval:	25 m
No. of channels:	96
Streamer depth:	10 m for lines 91/1-14 & 91/26-31; 5 m for lines 91/15-25
Airgun depths:	As above
Neartrace offset:	182-201 m for lines 91/1-14 & 91/26-31; 160-182 m for lines 91/15-25 (Hervey Bay area)
Recording fold:	24
Record length:	12 seconds
Sample rate:	2 ms
Filter settings:	8 Hz low cut; 128 Hz high cut
Field tape density:	6250 bpi
Tape format:	SEG-Y (demultiplexed)

APPENDIX 7. HIFIX-6 TRANSMITTER POSITIONS

Latitude / longitude / height above geoid

	AGD84	WGS72
Coolum Beach	26° 30.481' S 153° 05.106' E	26° 30.388' S 153° 05.161' E 70.4 m
Double Island Point	25° 56.259' S 153° 11.381' E	25° 56.166' S 153° 11.436' E 72.3 m
Fraser Island	25° 24.802' S 153° 10.099' E	25° 24.709' S 153° 10.154' E 73.8 m
Agnes Waters (Town of 1770)	24° 09.328' S 151° 53.206' E	24° 09.236' S 151° 53.261' E 75.7 m
Pialba	25° 16.977' S 152° 44.278' E	25° 16.885' S 152° 44.333' E 73.6 m
Bargara	24° 51.149' S 152° 28.732' E	24° 51.057' S 152° 28.787' E 74.5 m

........Height of mast is 30.0 m

APPENDIX 8. NON-SEISMIC DATA CHANNELS

The following is a list of channel allocations for the non-seismic data for Survey 91.

The main data set is saved on magnetic tape every minute in blocks of 128 x 6 floating point words. This represents 128 data channels of 6 records per block.

1	Survey and day number (SS.DDD) from RTE clock
2	Acquisition GMT (.HHMMSS) from RTE clock
3	Acquisition GMT (.HHMMSS) from master clock
4	Latitude, best estimate (radians)
5	Longitude, best estimate (radians)
6	Speed, best estimate (knots)
7	Course, best estimate (degrees)
8	Magnetometer # 1 (gammas)
9	Magnetometer # 2 (gammas)
10	Depth from 3.5 kHz (metres)
11	Depth from 12.5 kHz (metres)
12	F/A Magnavox sonar doppler (4000 counts/nm)
13	P/S Magnavox sonar doppler (4000 counts/nm)
14	F/A Raytheon sonar doppler (193.5 counts/nm)
15	P/S Raytheon sonar doppler (193.5 counts/nm)
16	Paddle Log (7000 counts/nm)
18	S-G Brown gyro heading (degrees)
19	Robertson gyro heading (degrees)
20	Sperry gyro heading (degrees)
25	HiFix A range (centilanes)
26	HiFix B range (centilanes)
27	HiFix C range (centilanes)
28	HiFix D range (centilanes)
29	HiFix E range (centilanes)
30	HiFix F range (centilanes)
39	GPS north std dev (metres)
40	GPS east std dev (metres)
41	GPS satellite numbers
42	GPS time (GMT seconds)
43	GPS Dilution of Precision
44	GPS latitude (radians)
45	GPS longitude (radians)
46	GPS height above geoid (metres)
47	GPS speed (knots x 10)
48	GPS course (degrees x 10)
49	GPS frequency bias
50	GPS GMT (.HHMMSS)

51	Latitude	from	Magnavox	Sonar	Doppler		(radians)
52	Longitude	"	"	"	"		(radians)
53	Speed	"	"	"	"		(knots)
54	Course	"	"	"	"		(degrees)
55	Latitude	from	Raytheon	Sonar	Doppler		(radians)
56	Longitude	"	"	"	"		(radians)
57	Speed	"	"	"	"		(knots)
58	Course	from	Raytheon	Sonar	Doppler		(degrees)
59	Latitude	from	Spare	Log			(radians)
60	Longitude	"	"	"			(radians)
61	Speed	"	"	"			(knots)
62	Course	"	"	"			(degrees)

63	Latitude from HiFix	(radians)
64	Longitude " "	(radians)
65	Speed " "	(knots)
66	Course " "	(degrees)
67	GMT from Magnavox MX1107 (seconds)	
68	Dead reckoned time from MX1107 (seconds)	
69	MX1107 latitude (radians)	
70	MX1107 longitude (radians)	
71	MX1107 speed (knots)	
72	MX1107 heading (degrees)	
73	GMT from Magnavox MX1142 (seconds)	
74	Dead reckoned time from MV1142 (seconds)	
75	MX1142 latitude (radians)	
76	MX1142 longitude (radians)	
77	MX1142 speed (knots)	
78	MX1142 heading (degrees)	
79	Gravity (mGal x 100)	
80	ACX (m/sec^2 x 10000)	
81	ACY (m/sec^2 x 10000)	
82	Sea state	
83	AGRF magnetic anomaly #1	
84	AGRF magnetic anomaly #2	
86	Shot time (HHMMSS)	
87	Shot point number	
88	Northerly set/drift (radians/10 seconds)	
89	Easterly set/drift (radians/10 seconds)	
94	HiFix A cumulative drift (centilanes)	
95	HiFix B cumulative drift (centilanes)	
96	HiFix C cumulative drift (centilanes)	
97	HiFix D cumulative drift (centilanes)	
98	HiFix E cumulative drift (centilanes)	
99	HiFix F cumulative drift (centilanes)	
104	HiFix A 10 sec drift (centilanes)	
105	HiFix B 10 sec drift (centilanes)	
106	HiFix C 10 sec drift (centilanes)	
107	HiFix D 10 sec drift (centilanes)	
108	HiFix E 10 sec drift (centilanes)	
109	HiFix F 10 sec drift (centilanes)	

The GPS channel 41, which holds the total number and the satellite numbers of the satellites in the current constellation, has data packed as follows; the units of value in the channel gives the number of satellites used, and the remainder gives a bit representation of the satellite number. For example; 1602 would imply 2 satellites (the units) leaving 160 which indicates satellites 5 and 7 (bits 5 and 7).

Transit Satellite Fixes

The Transit satellite fix information from both the MX1107 and MX1142 are saved in blocks of 20 floating point words when the fix data becomes available. The data from each satnav is in a similar format, each being identified by the first word.

1	1107 or 1142
2	Day number (1107) or date (1142)
3	GMT
4	Latitude (radians)
5	Longitude (radians)
6	Used flag (0 = not used, 1 = used)
7	Elevation (degrees)
8	Iterations
9	Doppler counts
10	Distance from DR (nautical miles)
11	Direction from DR (degrees)
12	Satellite number
13	Antenna height (metres)
14	Doppler spread flags (1107 only)
.	" " "
.	" " "
20	" " "

APPENDIX 9. DRAFT SPECIFICATIONS FOR BMR SEISMIC DATA ACQUISITION

Cable Specifications

Depth

Cable depth to be maintained at +/- 25% of specified depth.

Depth Transducers

No more than 2 cable depth transducers to be out of action at the start of a line. Transducers to be accurate to 0.5 metres. The first and last transducers must operate.

Noise

Noise tests to be run at the start and end of each line or every 4 hours. Tests at the start and end of line to consist of at least 5 records without guns firing. Noise levels are the mean of up to 1024 samples taken from each channel over the length of the record, averaged over the number of channels for a single record.

The allowable noise level for the 20 channels nearest to the stern and the last 1-3 channels is 6 microbars (30 microvolts for a cable with 5 V/bar sensitivity). The allowable noise level for the remaining channels is 4 microbars (20 microvolts for a 5 V/bar cable).

Leakage and Crossfeed

Leakage between channels no greater than 1 megaohm.

Dead Channels

There should be no more than 2 dead traces in the near 48 channels and no more than 3 in the far 48 channels, with no more than 5 dead traces in total.

Streamer Deviations

The feathering angle should not exceed 8 degrees. (This may be relaxed depending on local conditions and the geological target.)

The feathering angle is to be monitored every hour while on line and every 10 minutes coming onto line, and is to be entered in ships log.

The vessel will come onto line a minimum of 1.5 cable lengths before the start of the line.

Airgun Array Source Specifications

Pressure

Airgun operating is pressure 1800 psi. The lowest acceptable pressure is 1600 psi.

Checks

Prior to deployment individual guns to be checked at the start of each line for correct operation. No more than one gun in each array to be faulty. All gun sensors to be tested and no more than two to be faulty prior to deployment.

Array Performance

No more than 2 guns out of 20 over the 2 arrays to be out of action. A gun is deemed out of action if it misfires or if its shot sensor malfunctions. At least one of each cluster type must be maintained. The cluster can be positioned anywhere within the 2 arrays.

Missed Shots

Shots are deemed to be missed if a gun misfires or if there is a spread of more than 2 msec. in the firing time. For the 96 channel recording system collecting 48 fold data, the maximum allowable number of missed shots is 10 in succession or 5% of the total line length.

In the case of a line being terminated due to missed shots it may be resumed at the position of the last good shots.

Amplifiers and Filters

Frequency of Testing

Amplifiers and filters to be tested at the start of each line.

APPENDIX 10. OFFSHORE EXPLORATION WELL DETAILS

AQUARIUS-1

Location:	22° 37' 13" S / 152° 39' 02" E
Operator:	Australian Gulf Oil Company
Tenement holder:	Australian Oil and Gas Corp. Ltd
Vessel:	E.W. Thornton
Classification:	Wildcat
Spud date:	21/1/1968
Rig release date:	27/3/1968
Drilling data:	TD 8695 ft
	KB 32 ft to water
	WD 213 ft
Status:	Plugged and abandoned / dry hole

CAPRICORN-1A

Location:	22° 42' 14" S / 152° 16' 55" E
Operator:	Australian Gulf Oil Company
Tenement holder:	Australian Oil and Gas Corp. Ltd
Vessel:	E.W. Thornton
Classification:	Wildcat
Spud date:	22/11/1967
Rig release date:	15/1/1968
Drilling data:	TD 5609 ft
	KB 32 ft to water
	WD 347 ft
Status:	Plugged and abandoned / dry hole

APPENDIX 11. CRUISE NARRATIVE

(All times are local; 1100 local = 0000 GMT)

Friday 17 November
RV Rig Seismic sailed from Pyrmont 12, Sydney, at 1230 hrs on transit to the first survey area SE of Fraser I. Starboard magnetometer was drained and refilled, then deployed during transit to test its operation and that of the new boom deployment system. Both performed well.

Saturday 18 November
Fire/man-overboard drill was conducted, followed by a safety meeting.

Sunday 19 November
Off Mooloolaba, 1st mate Victor Bhagwat joined the ship via pilot boat. A sample of contaminated Sol-T (seismic streamer fluid) was sent back with the pilot for analysis. Began sampling program at 0830 on Barwon Bank; three dredge hauls were made in water depths of 30-100 m at two sites. Cemented quartz sand was recovered from the eastern side of the bank. Two dredges were lost due to hard irregular bottom, strong drift and poor control provided by the tensiometer when operating with only a short length of wire out. A bathymetry transect was run across the continental shelf slope to the east of Barwon Bank to confirm the suitability of a seismically-defined dredge site. Dredging commenced at about 2000 in 4000 m water depth.

Monday 20 November
The ship's No. 3 generator failed while the dredge was still on the bottom. The dredge was recovered with samples of semi-consolidated green-grey calcareous mud. The generator could not be repaired at sea, and it was decided to off-load it at Cairncross Dock, Brisbane, for repair and at the same time take aboard a supply of Sol-T in drums. The bulk Sol-T on the ship had been contaminated due to solution of the bituminous lining in the new tanks.

Tuesday 21 November
The port call also allowed a ship-shore gravity tie to be made. After loading 10 drums of Sol-T, the ship left Brisbane at 1200. Construction of the 2400 m seismic streamer commenced at 1830.

Wednesday 22 November
The streamer was fully deployed by 1400. A problem of noisy channels was traced to the tow-leader.

Thursday 23 November
The old spare tow-leader was patched up and transferred to the large seismic reel. A leaking section was replaced, the streamer balanced, cable levelers (birds) and airguns tested. Started seismic acquisition on line 91/001 at 2218. Airgun problems began to develop and acquisition was stopped while repairs and adjustments were made; a faulty stretch section was also replaced.

Friday 24 November
Seismic acquisition on line 91/001 re-commenced at 1139. A group of prawn trawlers was working the area off Double Island Point, so this line was terminated a little earlier than planned to avoid risking loss of the streamer. Started seismic line 91/002 at 2253, and deployed the magnetometer soon after.

Saturday 25 November
Started seismic line 91/003 (off Fraser I.) at 1542.

Sunday 26 November
Started seismic line 91/004 at 0032; sonobuoy 1 was deployed at 0048. There were a number of system crashes overnight, requiring that the ship loop back to re-shoot part of the line. Sonobuoy 2 was launched at 1410.

Monday 27 November
Seismic line 91/005 was started at 0429. Part of the line was re-shot because of a spate of system crashes. Sonobuoy 3 was launched at 2131.

Tuesday 28 November
Started seismic line 91/006 at 1235.

Wednesday 29 November
Started seismic line 91/007 at 1108.

Thursday 30 November
Started seismic line 91/008 at 0239, and line 91/009 at 1830.

Friday 1 December
Seismic line 91/010 commenced at 0809, with sonobuoy 4 being launched at 1045. At the end of the line in Wide Bay, a rendezvous with coastguard shark-cat was kept and Peter Petkovic plus airgun array spares were picked up. Bill McKay (2nd Mate) went ashore with the shark-cat. Seismic line 91/011 was started at 2142, and sonobuoy 5 deployed at 2255. A small deviation from the planned line was necessary to avoid fishing trawlers to the south of Double Island Point.

Saturday 2 December
Started seismic line 91/012, leading out of the survey area SE of Fraser I., at 0755. At 1847 there was a major failure of the HP seismic CPU. The ship circled while repairs were effected, and advantage of this opportunity was taken to carry out airgun and streamer maintenance.

Sunday 3 December
Three seismic sections with fish-bites were replaced. Seismic acquisition on line 91/012 was restarted at 1243. About 1 1/2 hours later, problems developed with the gun controller and it was decided to loop back and re-shoot part of the line. Re-shooting began at 1918.

Monday 4 December
Line 91/012 was completed at 0754, and after airgun maintenance, seismic line 91/013 was commenced at 1150. Sonobuoy 6 was launched at 1251.

Tuesday 5 December
Seismic acquisition on line 91/014, leading SE towards Hervey Bay, started at 1351. At the end of the line airgun maintenance was carried out, and the streamer and gun array prepared for shallow-water work in Hervey Bay. Lead was removed from the stretch sections and an extra Syntron bird fitted at the front of the streamer. Short 3 m ropes were fitted to the buoys on the gun array. Nominal streamer and airgun depth for the Hervey Bay work was 5 m. The first line in the Bay, line 91/015, was started at 2301.

Wednesday 6 December
Weather conditions in Hervey Bay were good and the seas smooth. At the end of line 91/015, the streamer was surfaced and inspected using the rubber dingy. This was done because some sections of the streamer had become noisy. Three wire crab-pots and floats which had caught on the streamer were removed; a holed stretch section was also replaced. Seismic lines 91/016 and 91/017 were completed.

Thursday 7 December
Seismic lines 91/018 and 91/019 were completed, and 91/020 started. Sonobuoy 7 was deployed on line 91/019 at 1228 and sonobuoy 8 was deployed on line 91/020 at 1841.

Friday 8 December
A sonobuoy (no. 9) launched shortly after the start of seismic line 91/021 was not successful (it may have caught on the streamer). A second, sonobuoy 10, released soon after at 0841 provided good data.

Saturday 9 December
Seismic line 91/022 was completed and line 91/023 started at 0130. At the end of line 91/023, it was discovered that the starboard gun array and tow-leader had become entangled. The tangle probably occurred earlier on the line at the time the ship slowed briefly to avoid a collision with a trawler that cut across the bow of the ship. Though there was some damage to the plastic skin and a couple of strands of the armouring were broken, the tow-leader remained in serviceable condition. The streamer sections were transferred to the other tow-leader on the small seismic reel. Seismic line 91/024 was started at 1135 and line 91/025 (leading out of the Hervey Bay area) was begun at 2002.

Sunday 10 December
On completing seismic line 91/025 at 0334, the buoy ropes on the airgun arrays were changed back to 7 m length (allowing the guns to run at 10 m nominal depth) and the tow-leader (plus streamer) transferred to the large seismic reel. Seismic line 91/026 was started at 1003 and ended at 2115. Acquisition on line 91/027 began at 2231.

Monday 11 December
The seismic tie to the Aquarius-1 well-site was made. Seismic line 91/028 was then run to tie the Aquarius-1 and Capricorn-1A well-sites.

Tuesday 12 December
Seismic line 91/029, located along the axis of the Capricorn Basin, was commenced at 0315. Capricorn-1A was crossed at 0440. Sonobuoy 11 was deployed at 1151.

Wednesday 13 December
Seismic line 91/029 was completed at 0344. Major tape drive problems were encountered and it was necessary for the ship to loop a number of times while the problem was investigated and rectified. Seismic line 91/030 was started at 1105. At 1800 the ship headed SE onto seismic line 91/031.

Thursday 14 December
Seismic line 91/031 was completed at 0529 and this ended seismic acquisition for cruise 91. The seismic gear was aboard by about 1300, and the return transit to Sydney was begun. The magnetometer was deployed and non-seismic data acquisition continued on the way back through the survey area SE of Fraser I.

Friday 15 December
Weather deteriorated to very rough seas and large swell, making retrieval of the magnetometer difficult.

Saturday 16 December
The pilot was taken on board off Sydney at 1750. The ship berthed at Pyrmont 12 and was all fast at 1854; this marked the end of the cruise.

APPENDIX 12. SHIPBOARD SCIENTIFIC & TECHNICAL PERSONNEL

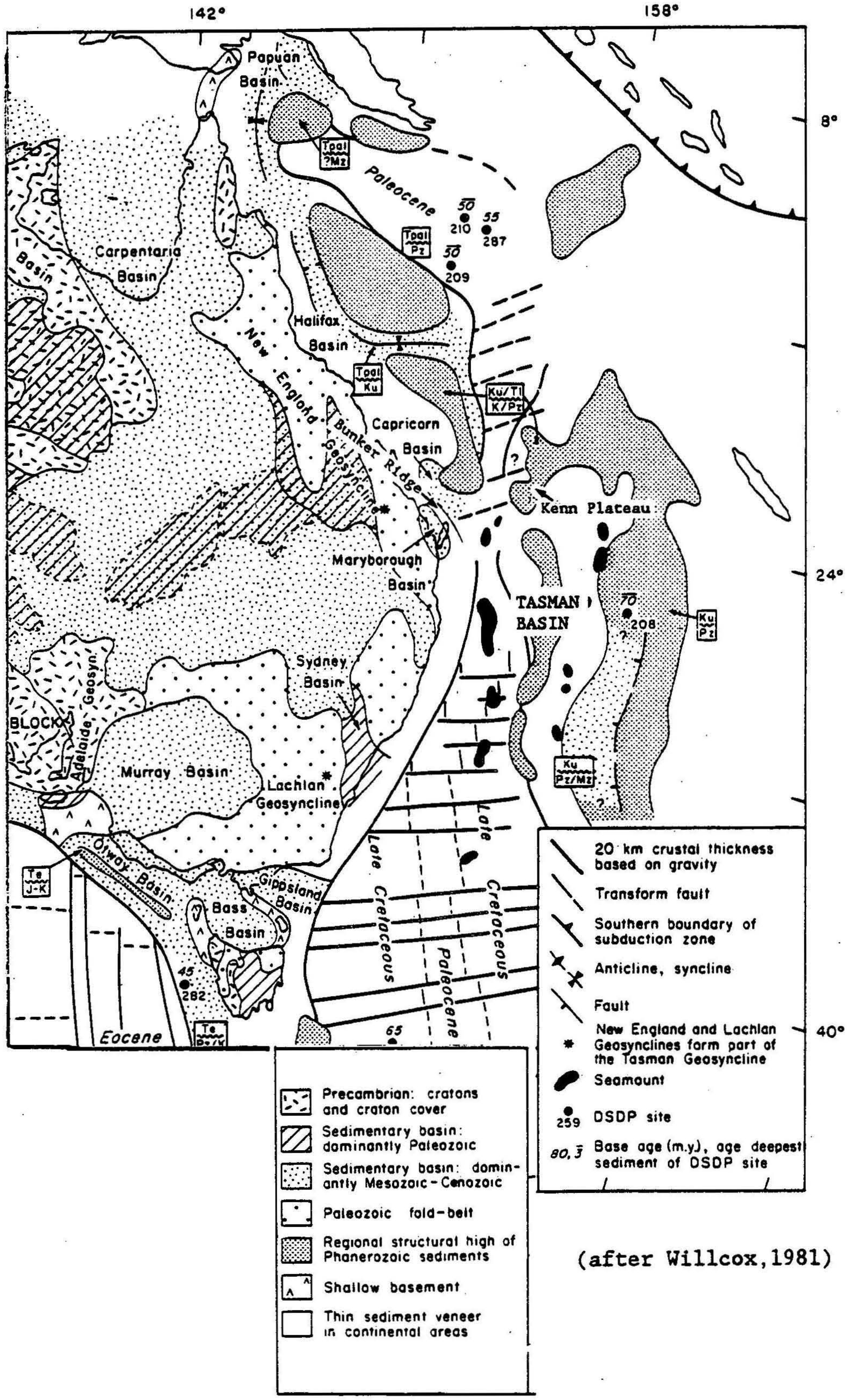
P.J. Hill	Co-chief scientist/ P.I.
C.J. Pigram	Co-chief scientist
D.J.L. Needham	Geophysicist
P. Petkovic	Scientist (on part of cruise)
F. Peedeman (ANU)	Geologist
H.M. Miller	Systems expert
G. Bernardel	" "
R. Curtis-Nuthal	Electronics technician
G. Burren	" "
J.W. Whatman	" "
J.P. Stratton	Science technician
G. Saunders	" "
E. Chudyk	" "
C.J. Lawson	" "
N.E. Clark	" "
T. McNamara	" "
C. Green	Mechanical technician
J. Roberts	" "
D. Sewter	" "
B.S. Dickinson	" "
G. Werch	" "

SURVEY		.	COMPANY	CONTRACTOR	TENEMENTS	SEISMIC SOURCE	CABLE	COVERAGE	MILEAGE
Bunker Group S.	64/4505	4.2.64 - 7.2.64	Shell Dev.	Western Geo.	ATP 70P (Q/13P)	Expl.	600 m - 600 m 1200 m - 1200 m	100% 200%	183.4 m (293 km
Hervey Bay S.	64/4569	8.3.65 -15.4.65	Shell Dev.	G. S. I.	ATP 70P (Q/13P)	"	1500 m	100% 400%	689 (1102 km)
Swain Reefs S.	65/11022	17.7.65 -24.8.65	Aust. Gulf Oil	Western Geo.	ATP 90P (Q/4, 5P, 3P)	"	600 m - 600 m 1200 m - 1200 m	400%	519 (830 km)
Capricorn Channel (Swain Reefs Phase II)	66/11093	20.8.66 -24.11.66	Aust. Gulf Oil	United G.C.	ATP 90P (Q/4, 5, 6, 13P)	Spkr.	8040 ft	400% & 600%	1839 expl. (305 spkr. (4
Hervey Bay S. R-1	69/3002	19.1.69 -23.9.69	Shell Dev.	B.I.P.M.	Q13P	A/G	2700 m	2400%	128 (205 km)
Hervey Bay S. R-2	–	9.3.70 - 20.3.70	Shell Dev.	G.S.I.	Q13P	A/G	2400m (active) 48ch	2400%	420
Gulf R & D Scientific Survey	73/21	22.2.73 -25.3.73	Gulf R & D	Gulf R & D	Q/4P, 5P, 6P, & 7P	Aquapulse	24 ch 1600m (active)	2400%	1374 (2199 km)
Offshore Qld Scientific Investigation	–	25.11.73 - 3.12.73 9.5.74 - 5.6.74	Shell Dev.	G.S.I.	–	A/G	2400 m (active) 48 ch	2400%	7482 km
Barrier Reef A/M	62/1714	7.3.62 - 4.4.62	A.O.G.	Aero Serv. Ltd	(Q/4P, 5P, 6P, 7P, 13P)				5545
Swain Reefs A/M	63/1712	14.5.64 -20.9.64	Aust. Gulf Oil	"	ATP-90P (Q/4P, 5P, 6P)				17668

S. = Seismic
A/M = Aeromagnetic

(after McAvoy & Temple, 1978; Baxman, 1971; Shell Development, 1977)

Table 1. GEOPHYSICAL PETROLEUM EXPLORATION SURVEYS, OFFSHORE MARYBOROUGH / CAPRICORN BASINS



(after Willcox,1981)

Fig. 1 Maryborough Basin, Kenn Plateau, Capricorn Basin location map and regional geological structures of the east Australian margin.

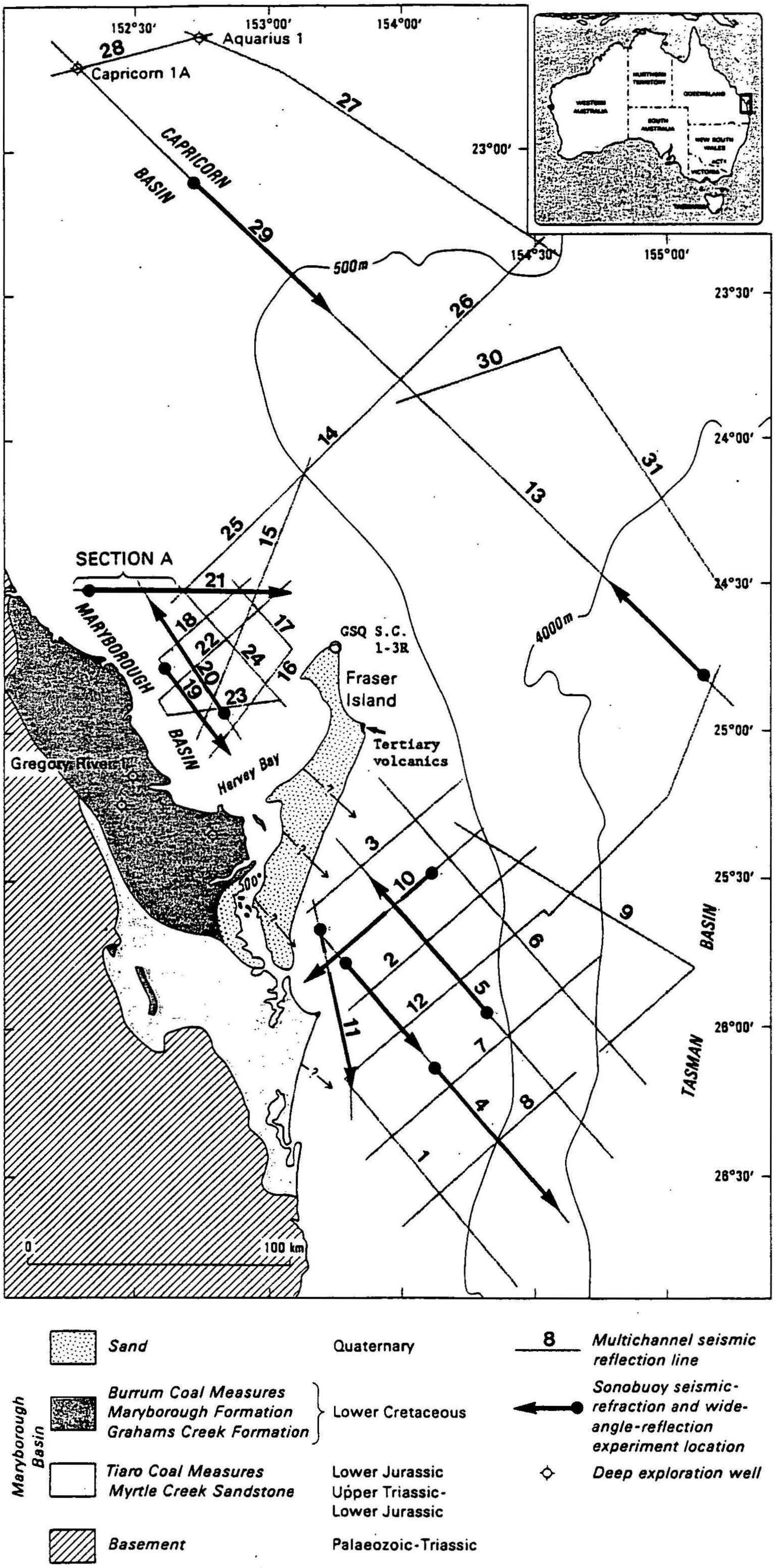
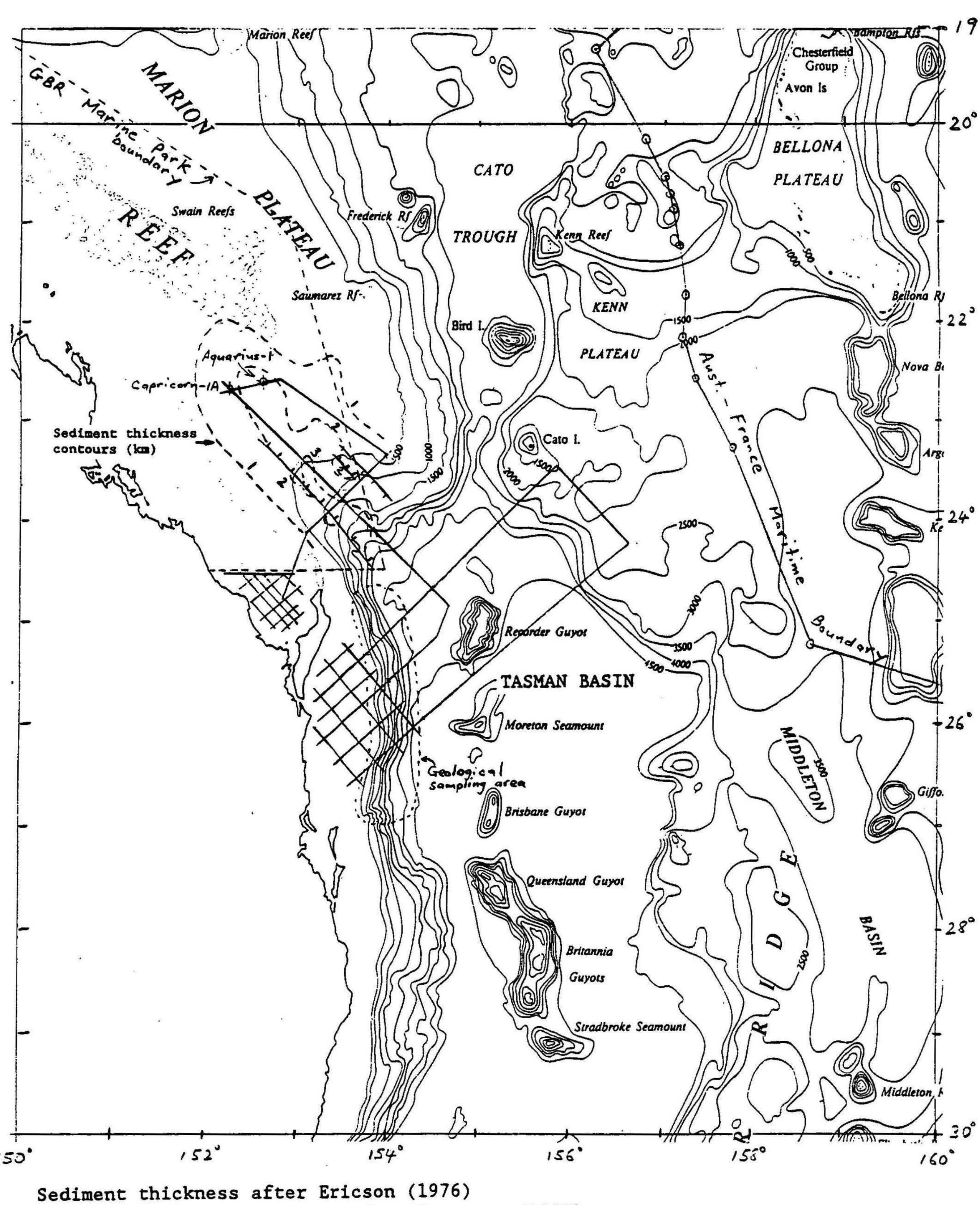
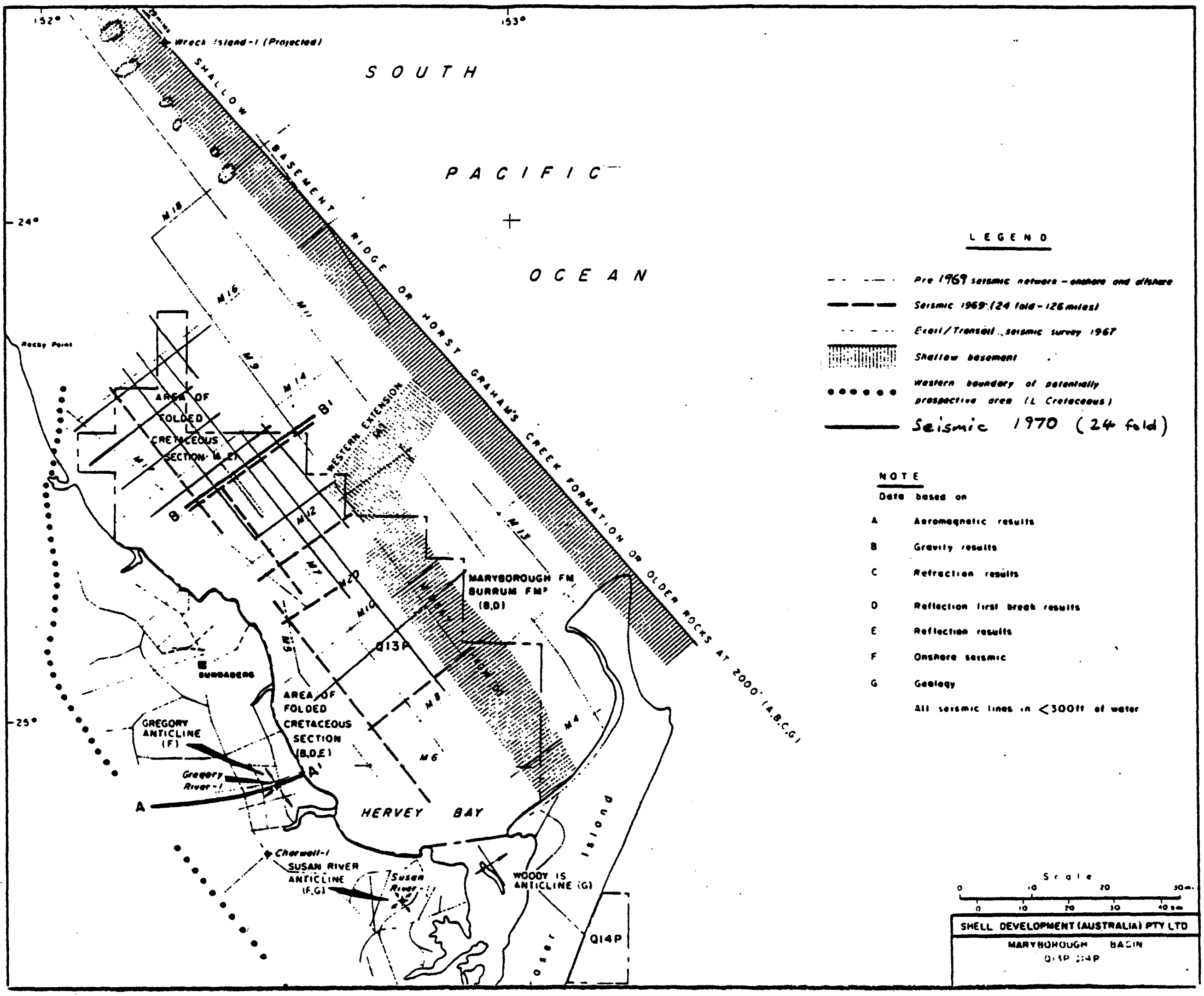


Fig. 2 Maryborough Basin geology / Survey 91 seismic lines and sonobuoy experiment locations.



Sediment thickness after Ericson (1976)
Australia - France boundary after Prescott (1985)
Bathymetry after Kroenke et al. (1983); contour interval 500 m.

Fig. 3 Proposed geoscience program - seismic survey lines & geological sampling area.



(after Tiger,1969)

Fig. 4 Pre-existing seismic network and principal structural elements, Hervey Bay area.

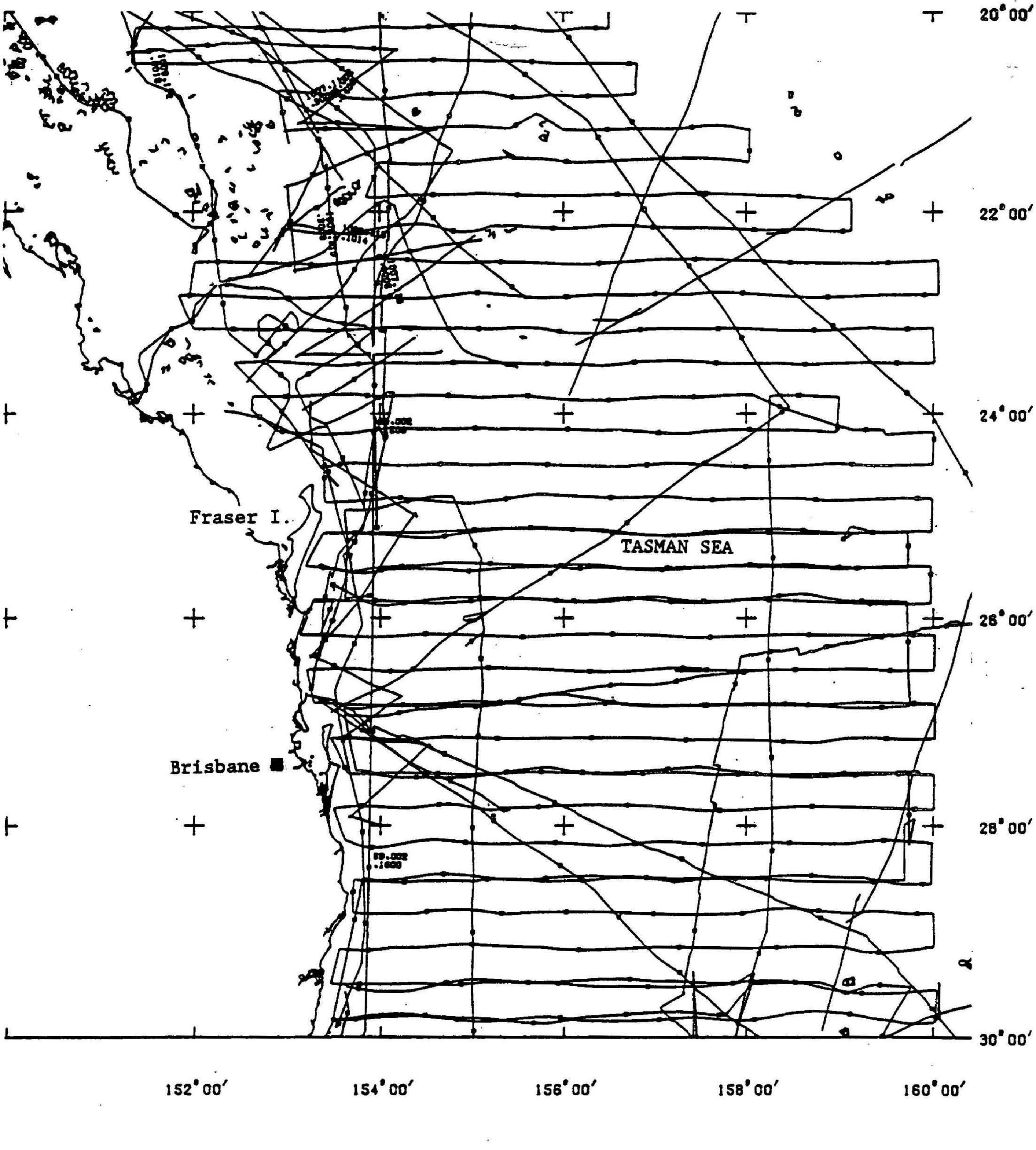


Fig. 5 Regional survey coverage - mainly BMR continental margin surveys (1970-73), Shell Development (1973/74) & Gulf (1973).

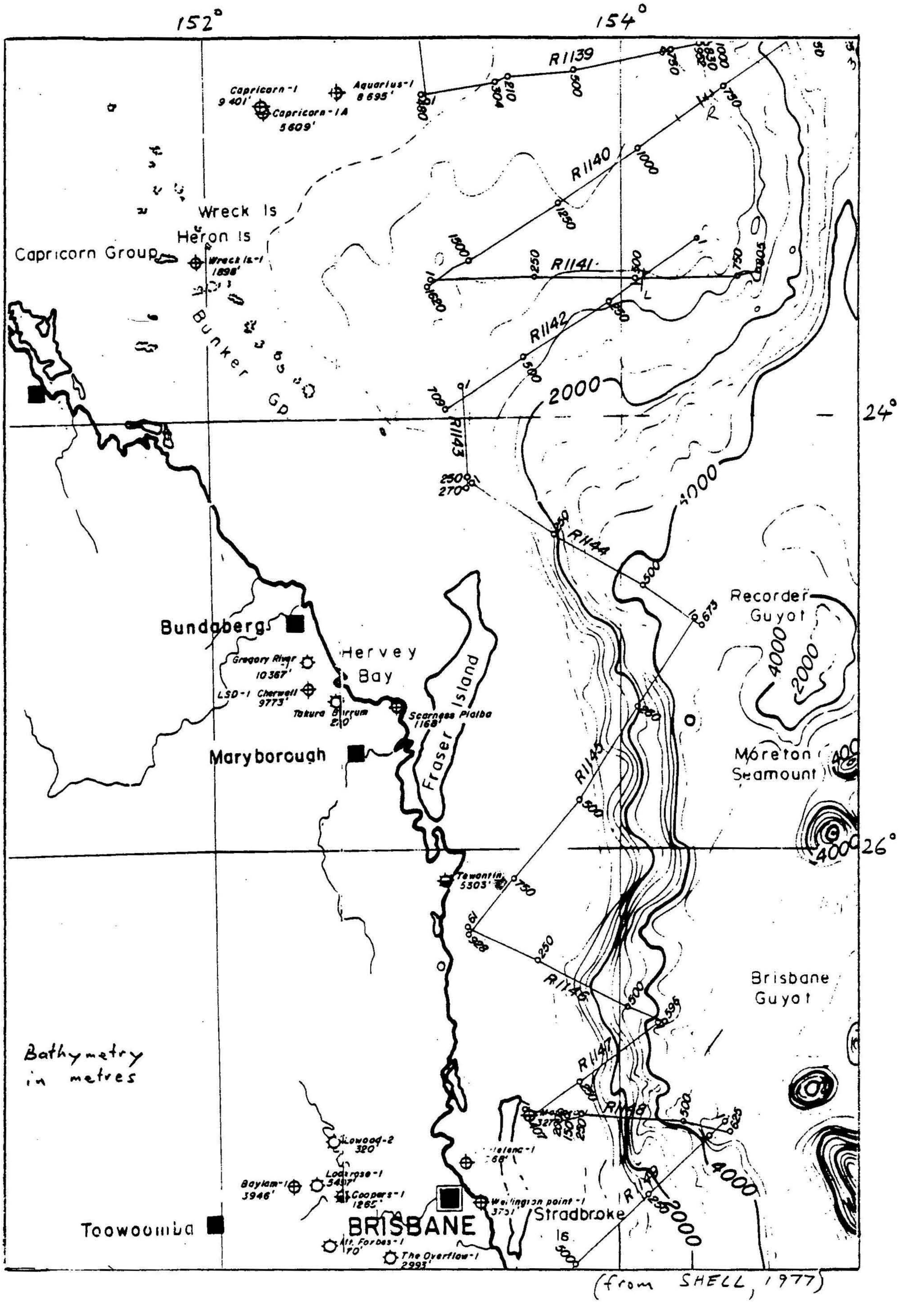
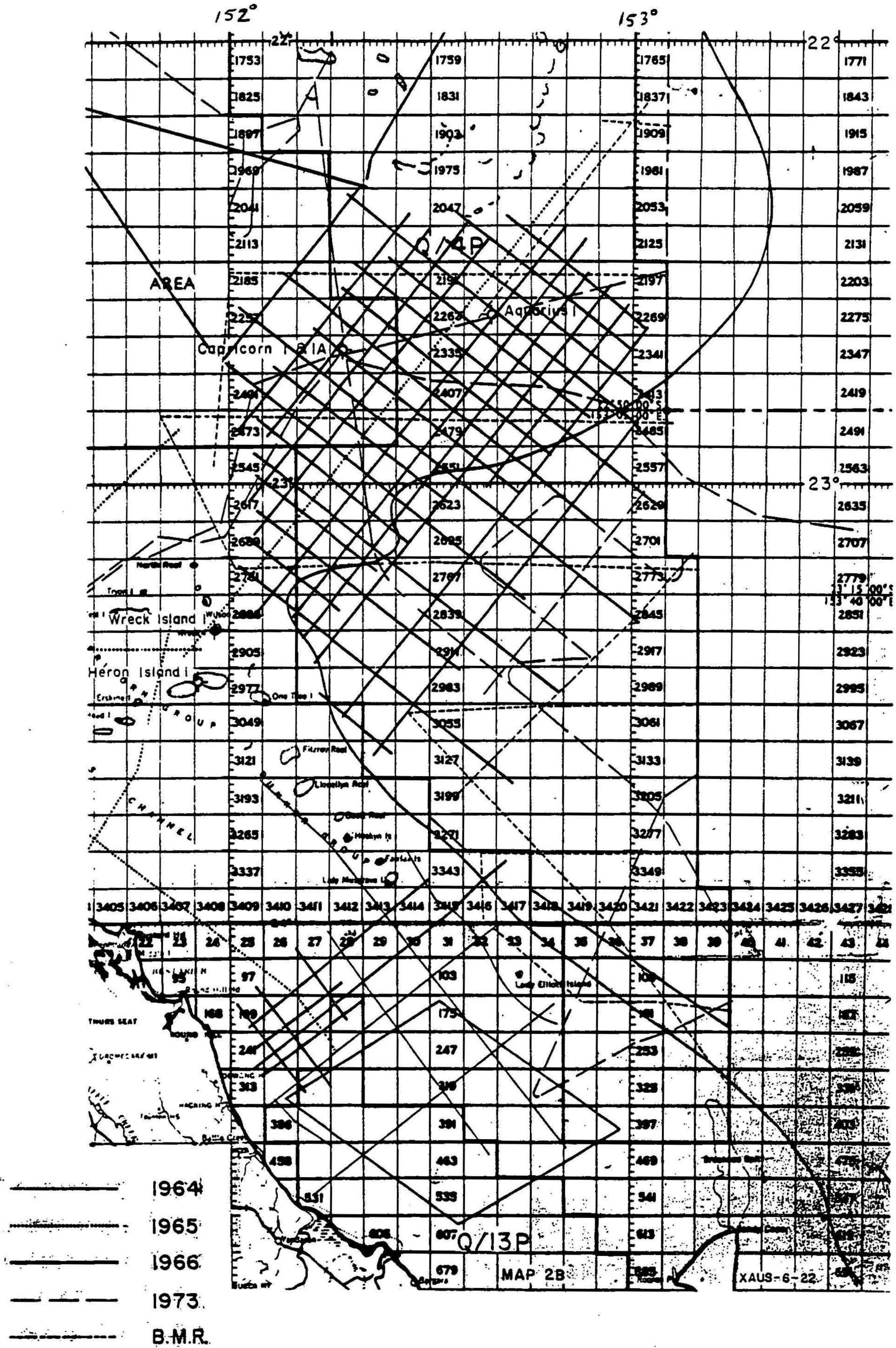


Fig. 6 Shell 1974 seismic reconnaissance survey lines & coastal/offshore well locations.



(after McAvoy & Temple, 1978)

Fig. 7 Seismic survey lines (company data) to 1973, Capricorn Basin.

? Kenn Plateau

? southern Queensland margin

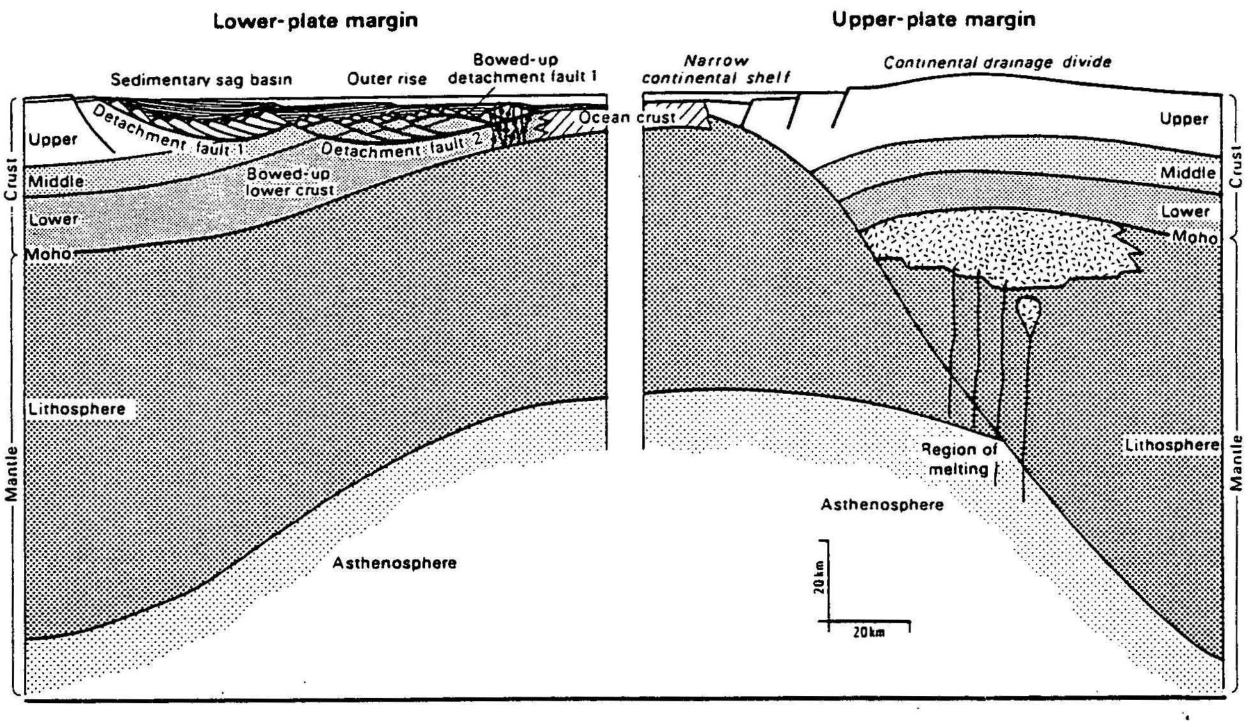
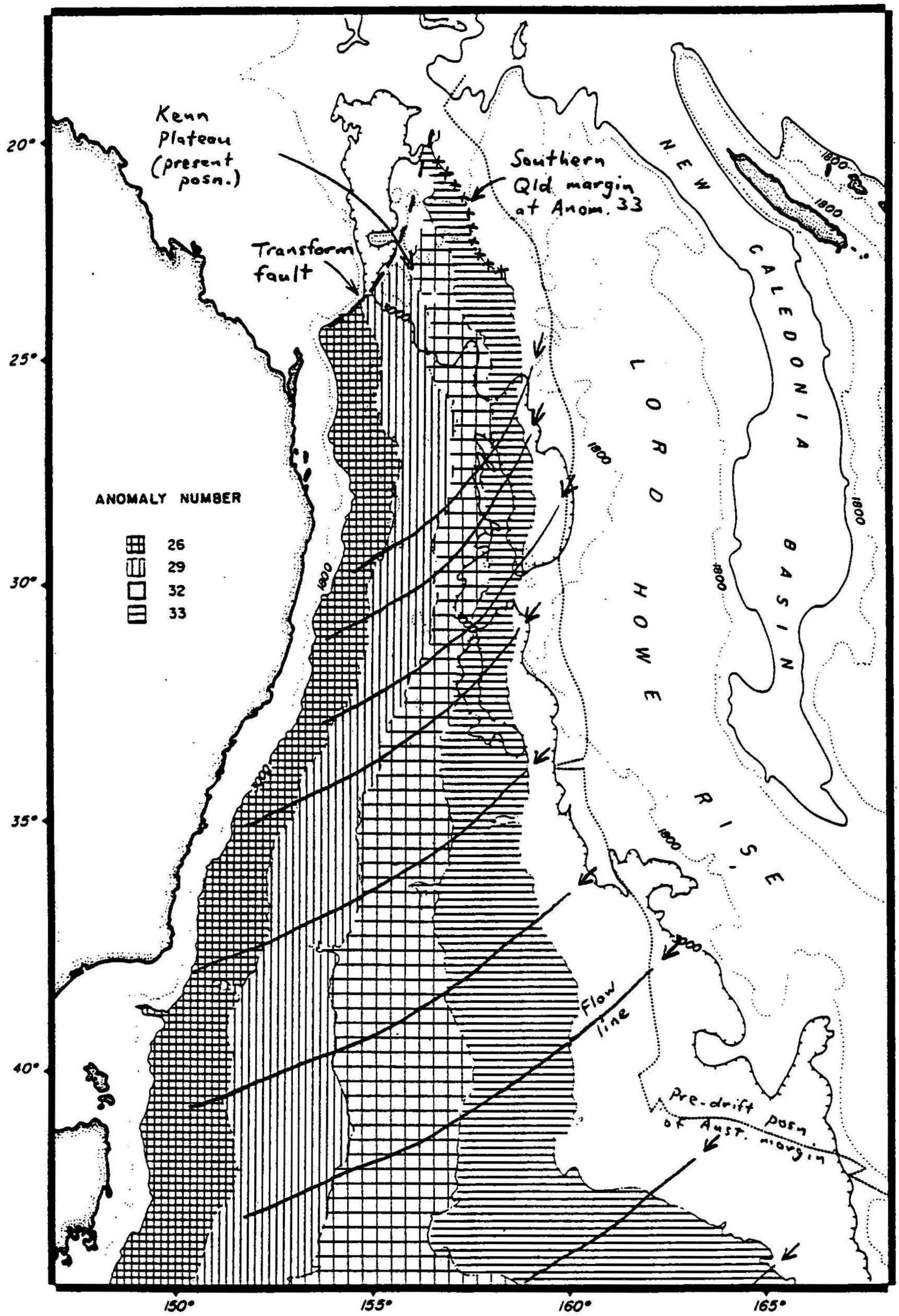


Fig. 8 Model of continental extension by detachment faulting (after Etheridge et al., 1989) that may be applicable to the southern Queensland/Kenn Plateau conjugate margins.



Movement of the east Australian continental margin relative to Lord Howe Rise (fixed).

Fig. 9 Opening of the Tasman Sea, after Weissel & Hayes (1977).

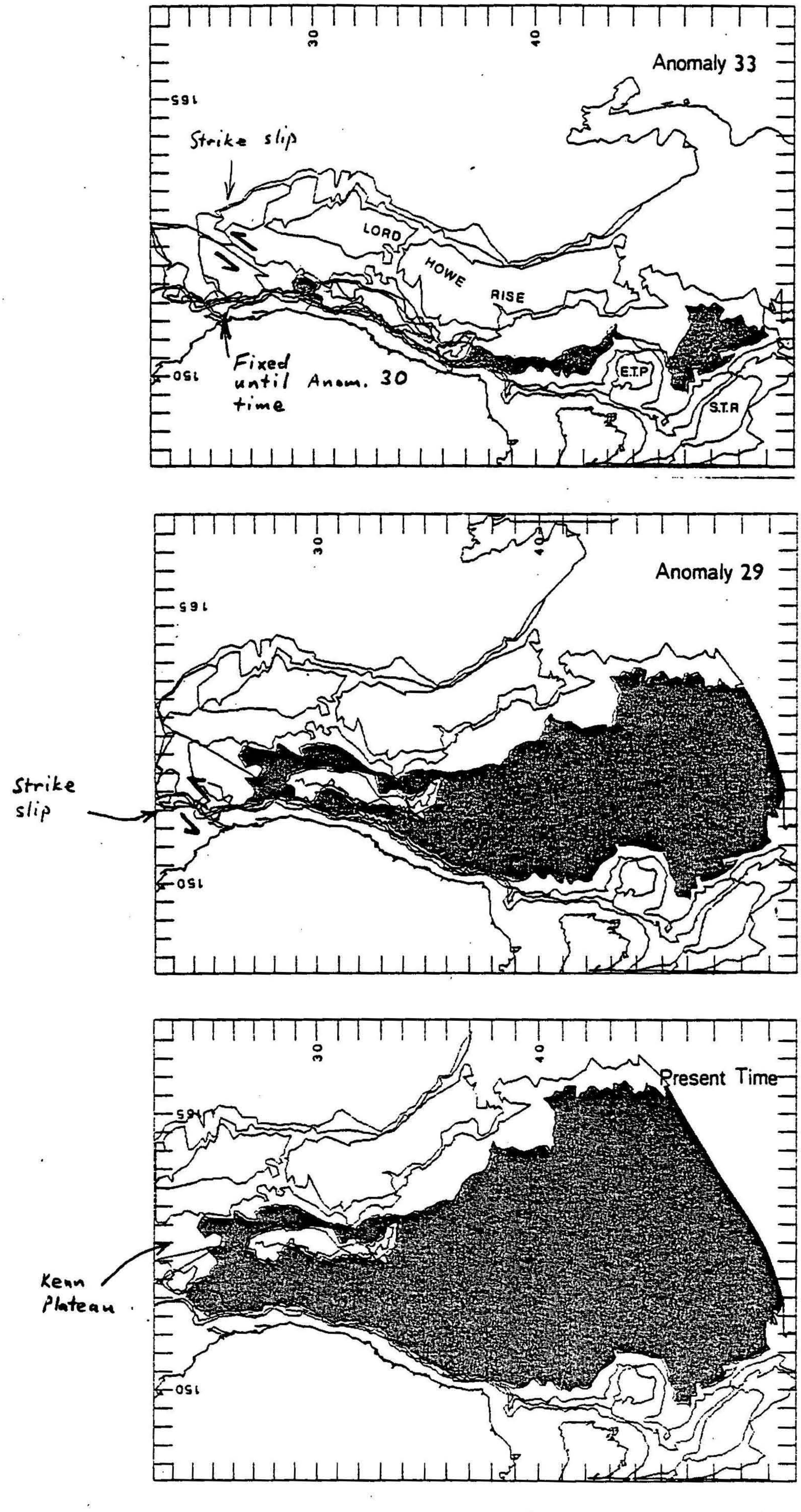


Fig. 10 Opening of the Tasman Sea, after Shaw (1978).

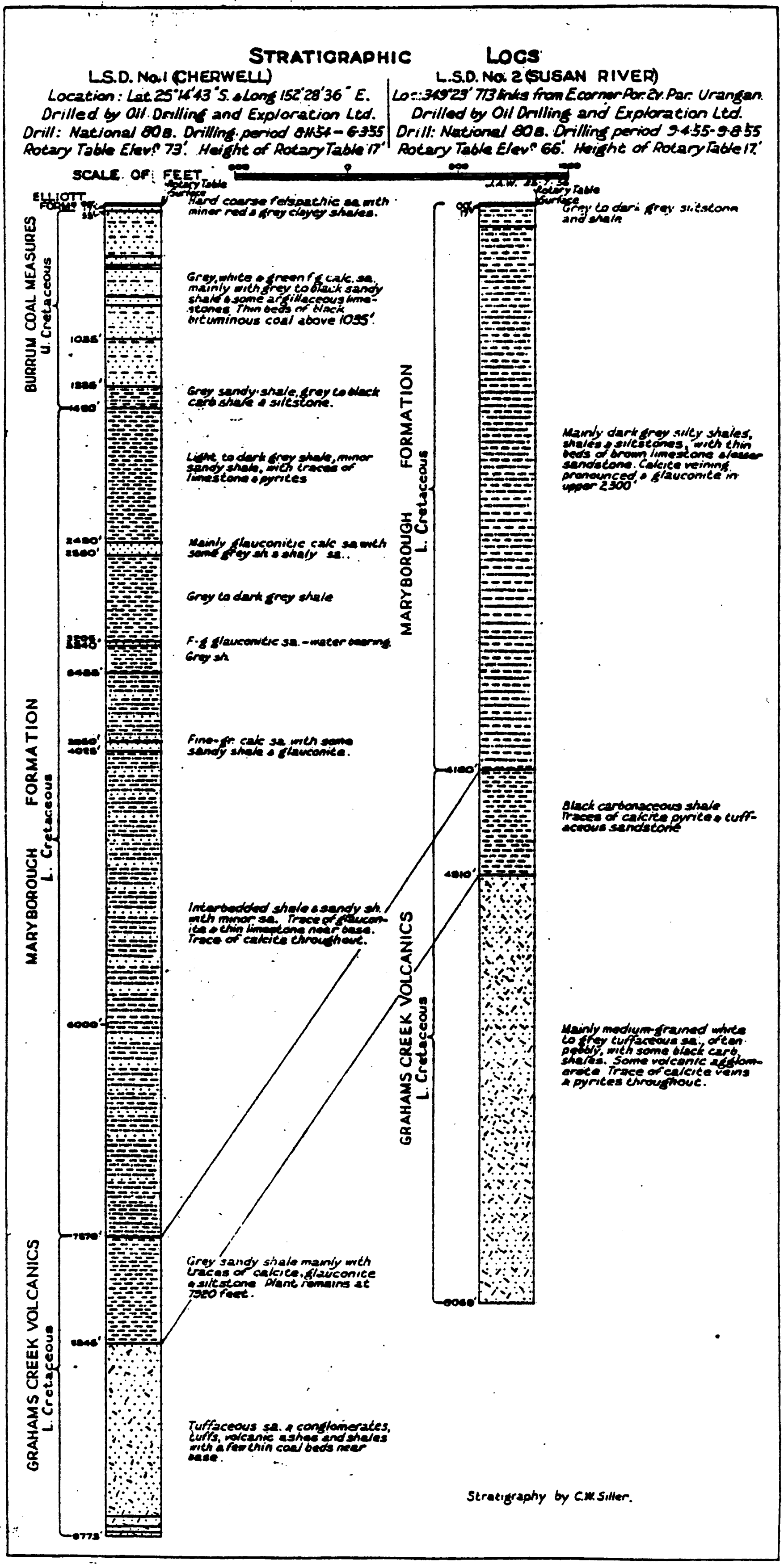
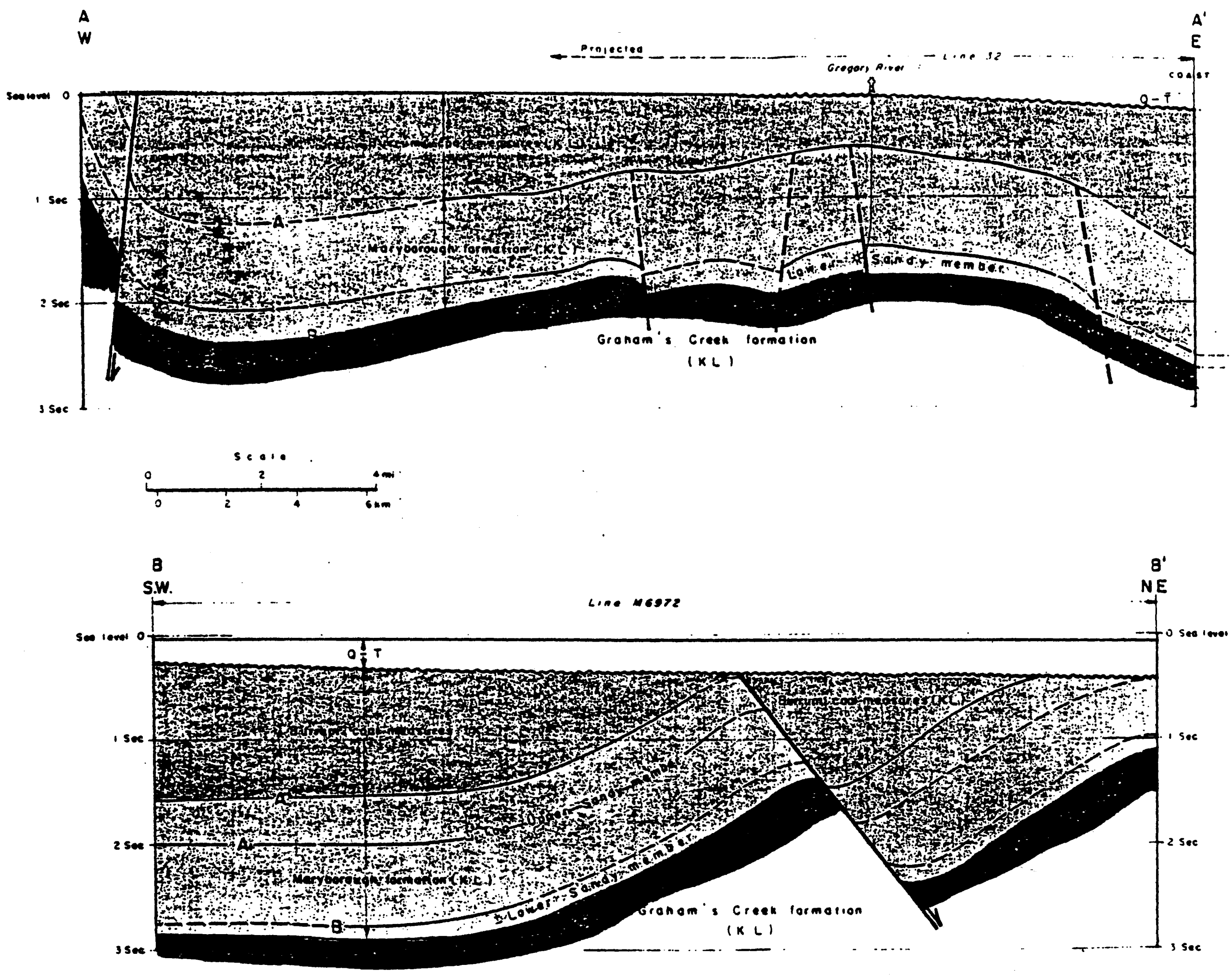


Fig. 11 Maryborough Basin exploration well stratigraphy (after Ellis, 1966).



For location of sections see Fig. 4.

Fig. 12 Interpreted cross-section, Maryborough Basin (after Tiger, 1969).

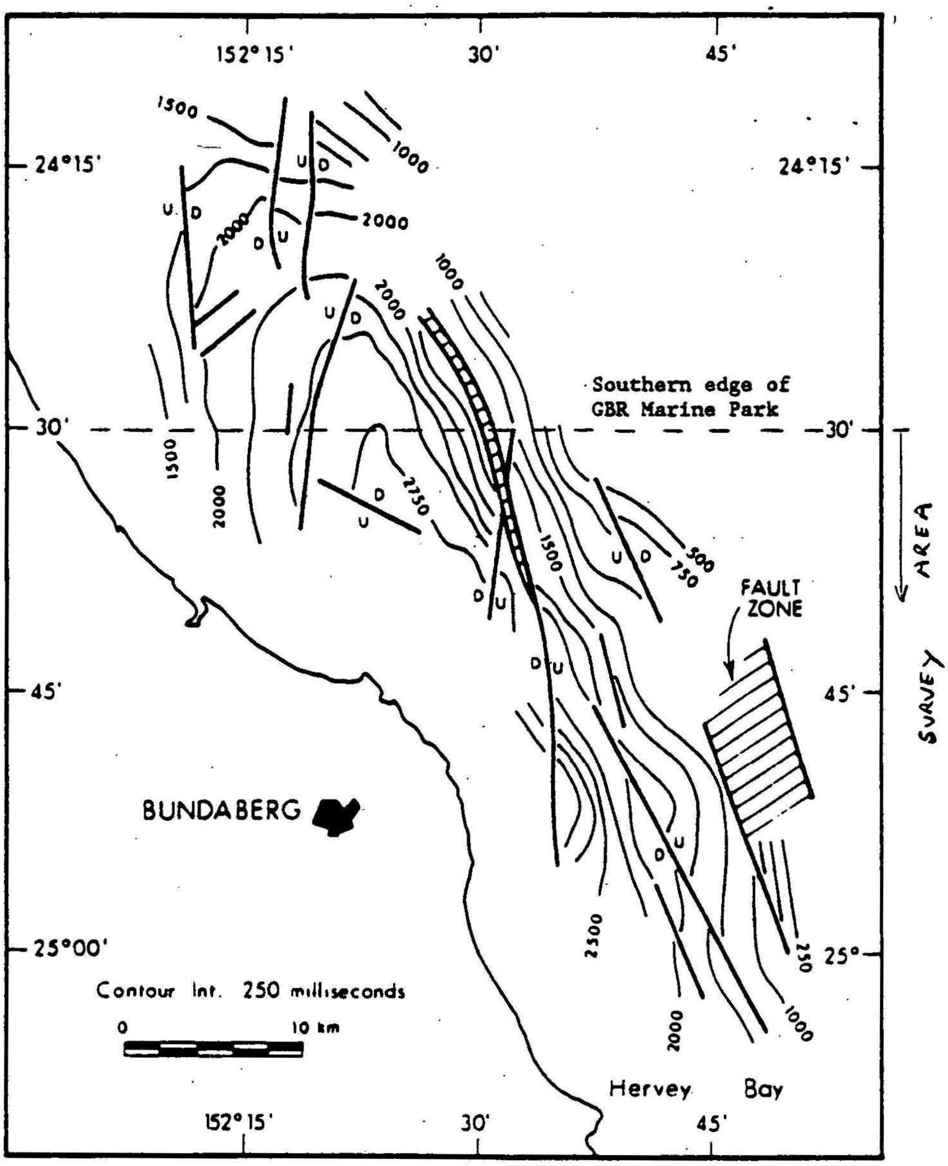
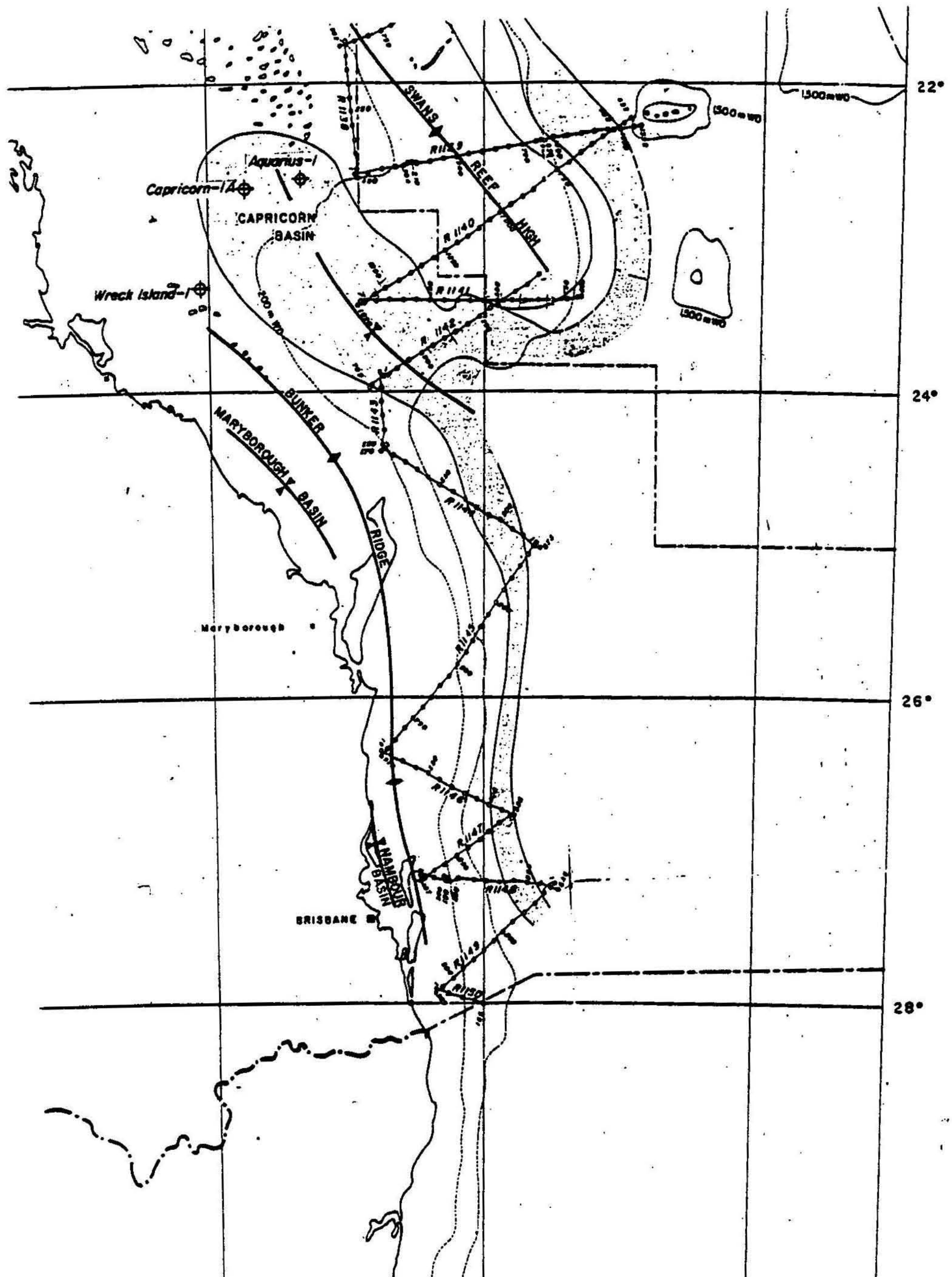


Fig. 13 Maryborough Basin - near top Grahams Creek Formation, structure contours (after Benbow, 1980).



(Shell Development, 1977)

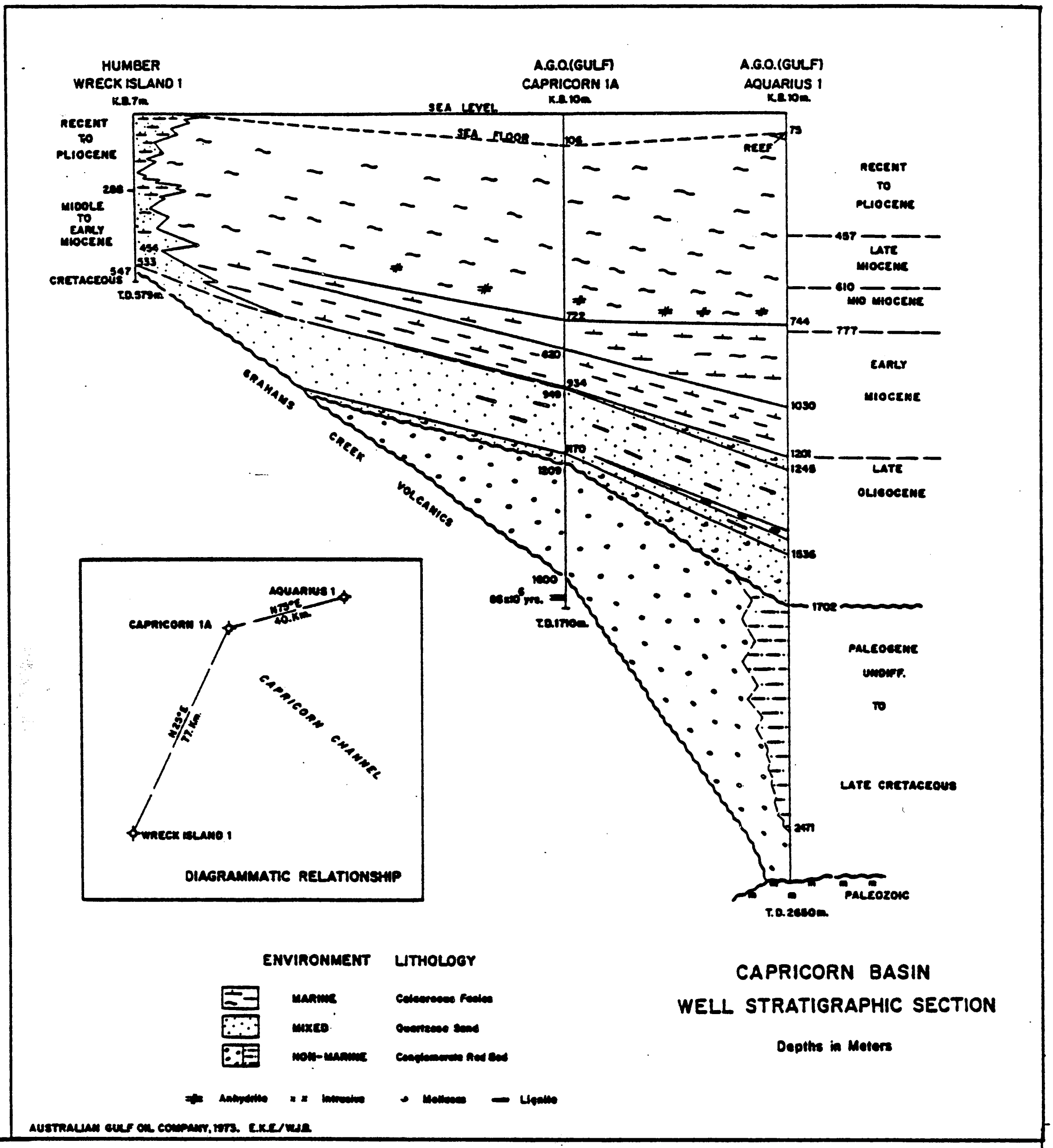
ANTICLINAL AXIS

SYICLINAL AXIS

MAJOR FAULT

AREAS OF SIGNIFICANT SEDIMENT THICKNESS

Fig. 14 Regional interpretation, Shell 1974 reconnaissance survey - SE Queensland continental margin.



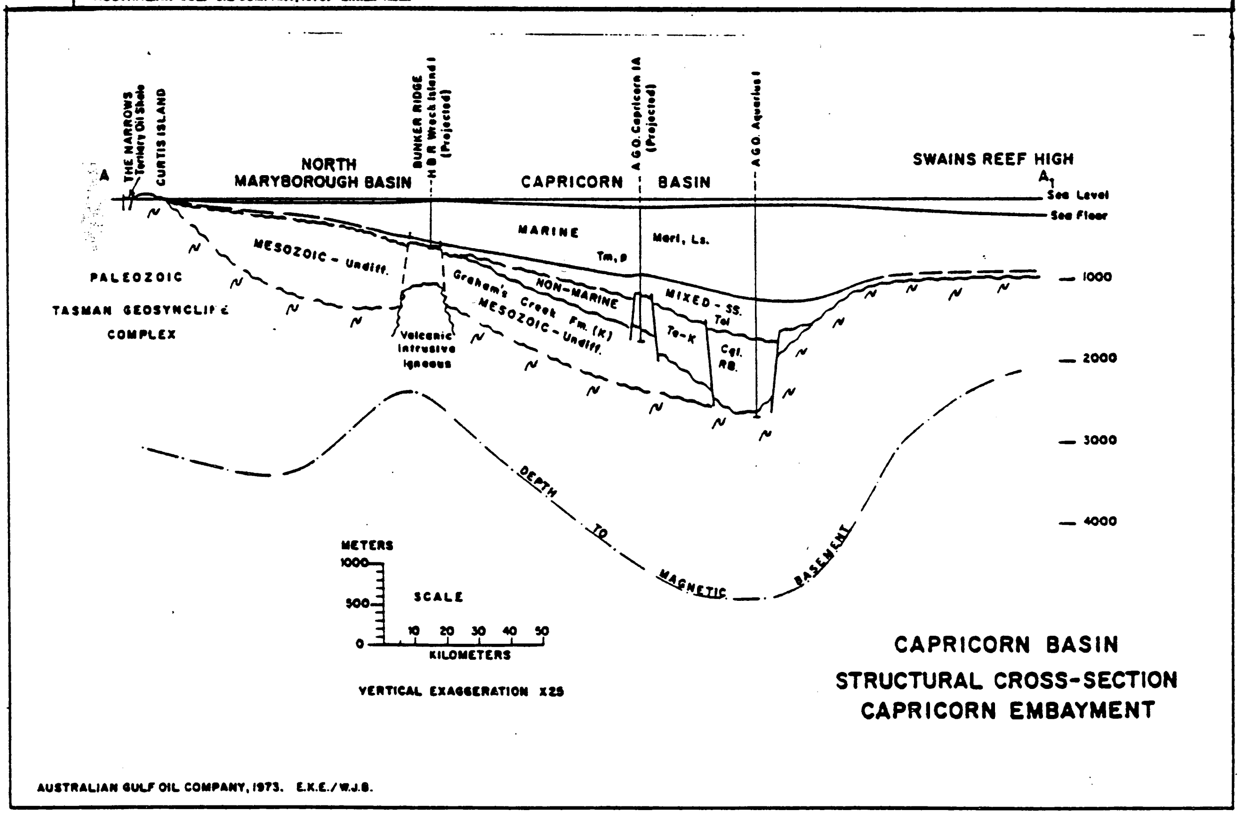


Fig. 15 Capricorn Basin well stratigraphy and regional correlations (from Ericson,1976).

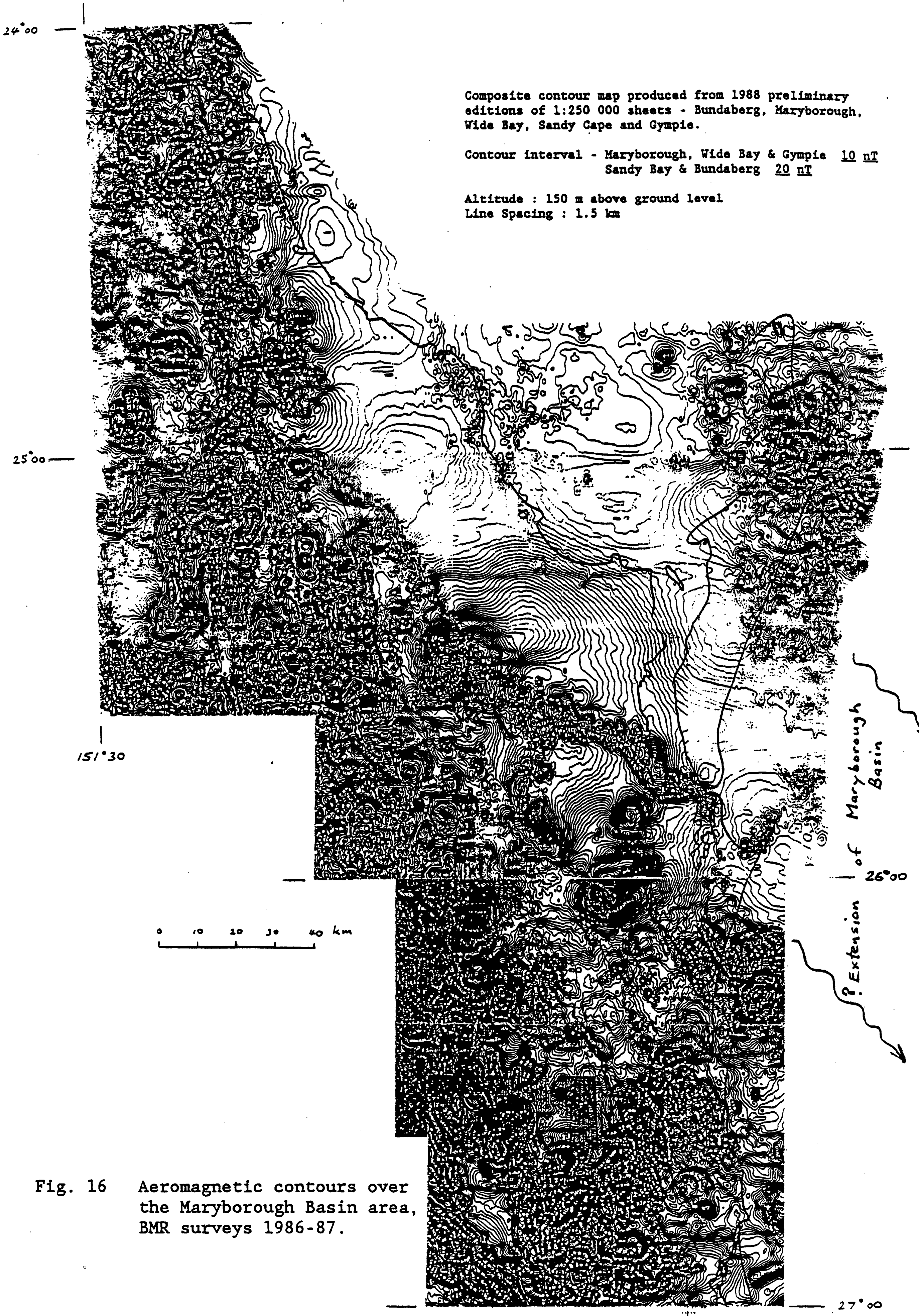


Fig. 16 Aeromagnetic contours over the Maryborough Basin area, BMR surveys 1986-87.

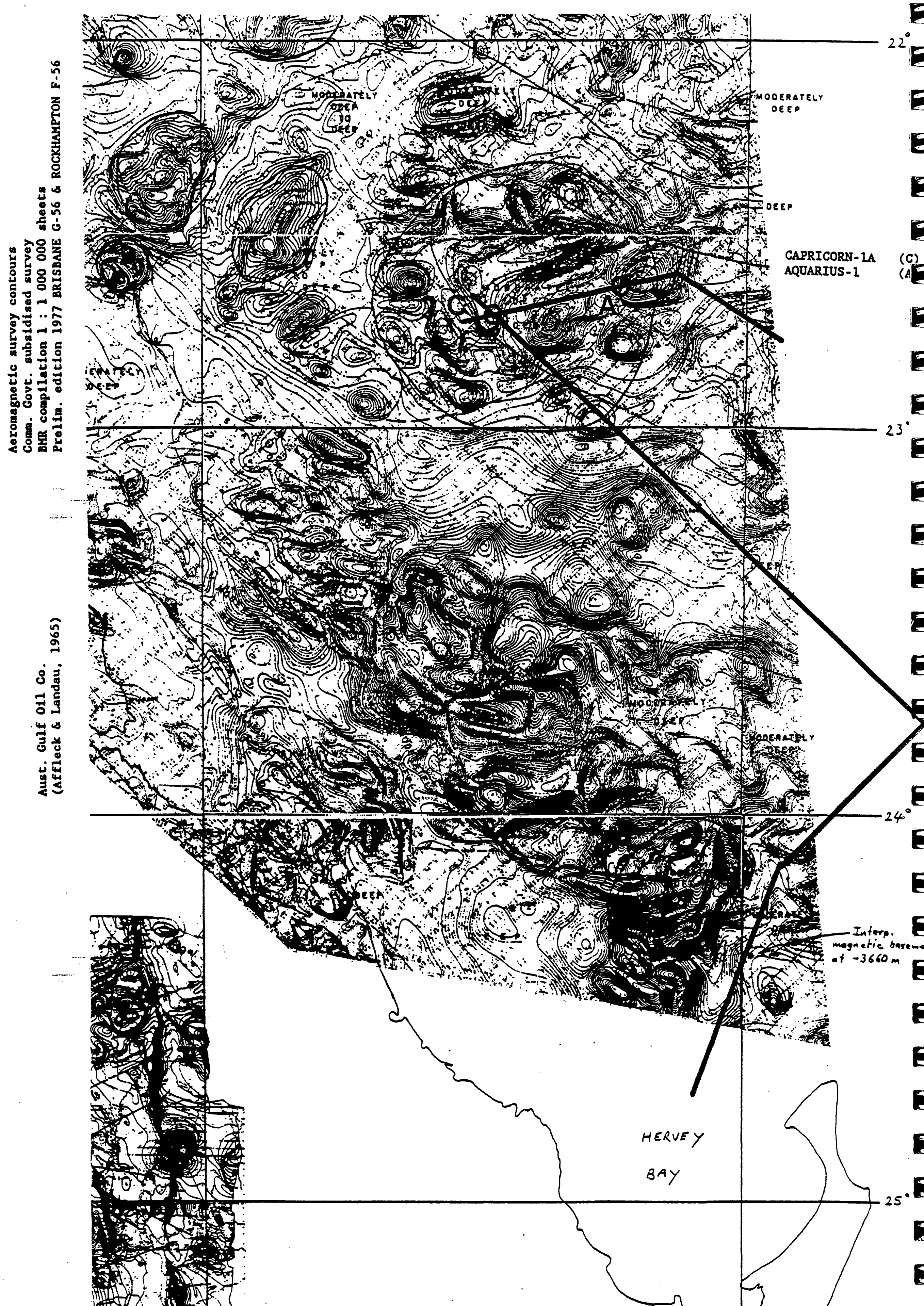


Fig. 17
Aeromagnetic contours, northern Maryborough Basin & Capricorn Basin with proposed seismic tie Hervey Bay - Capricorn-1A / Aquarius-1 wells.

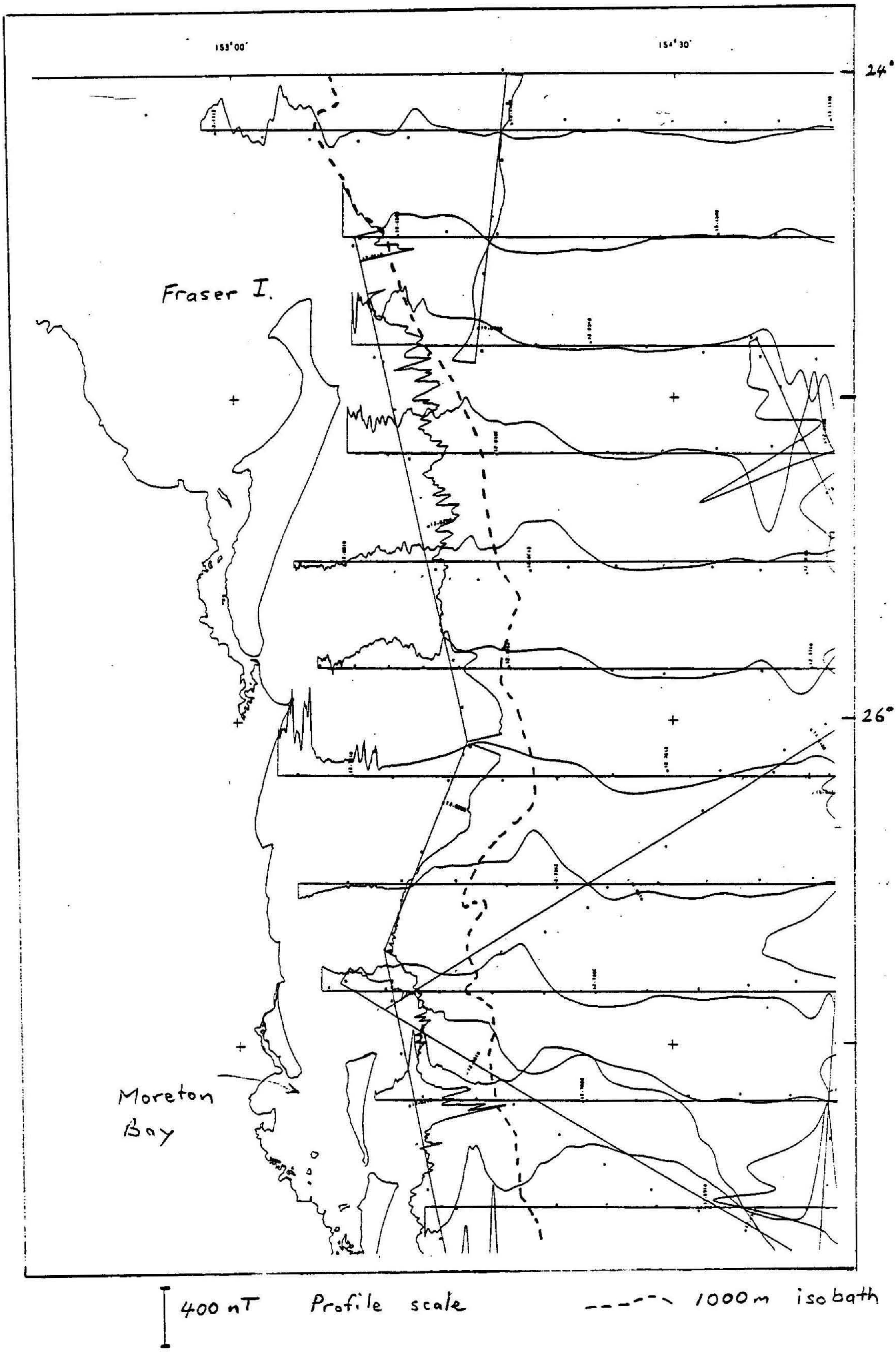


Fig. 18 Magnetic anomaly profiles, Fraser Island - Moreton Bay, BMR surveys 1970-73.

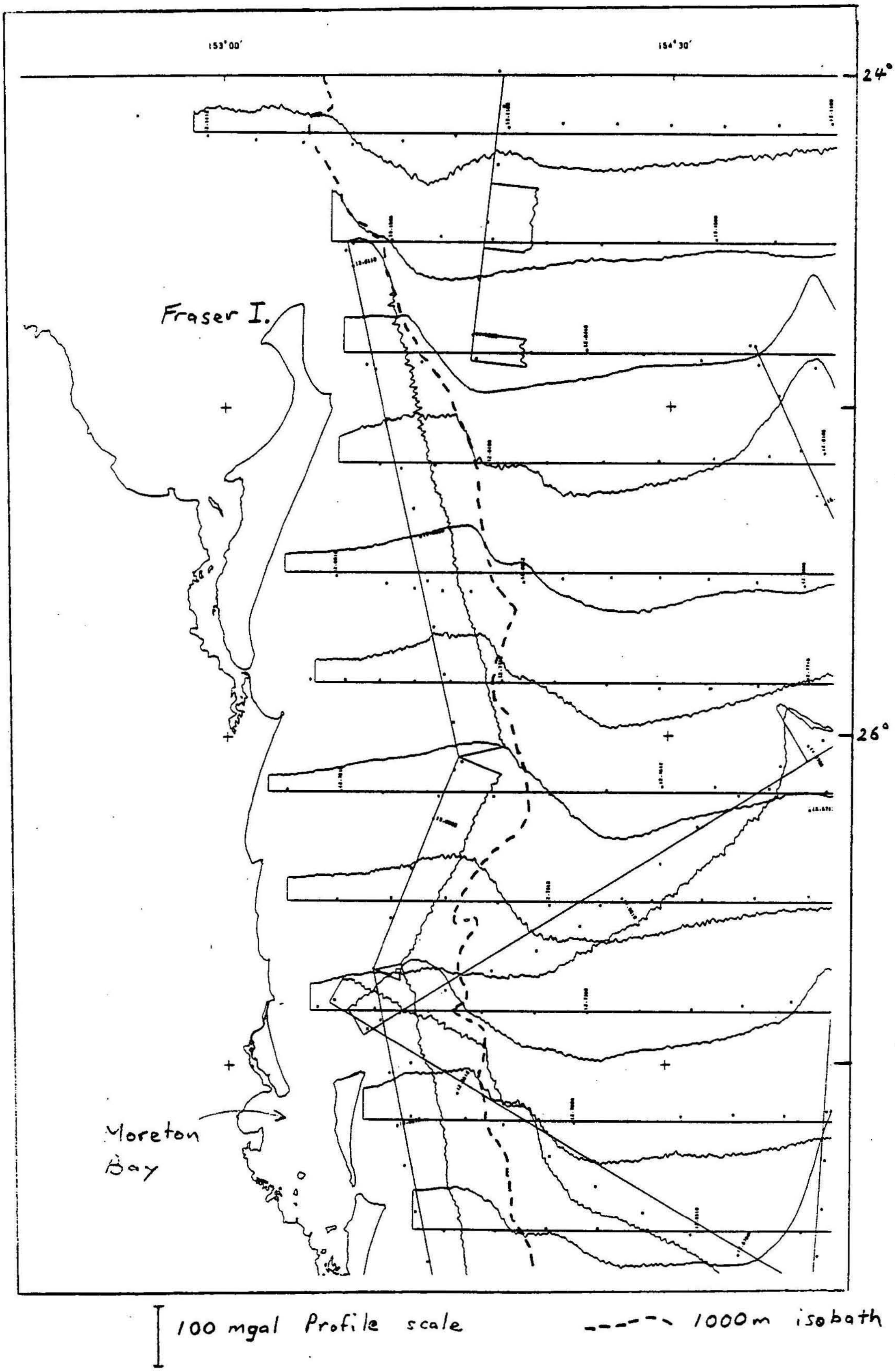
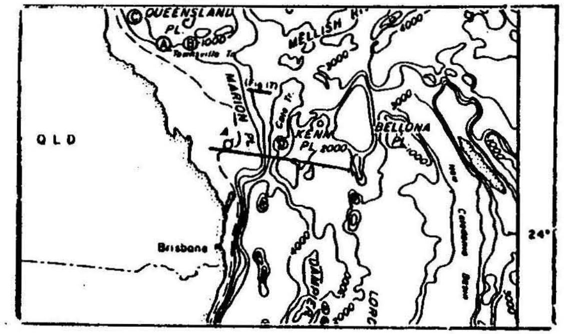
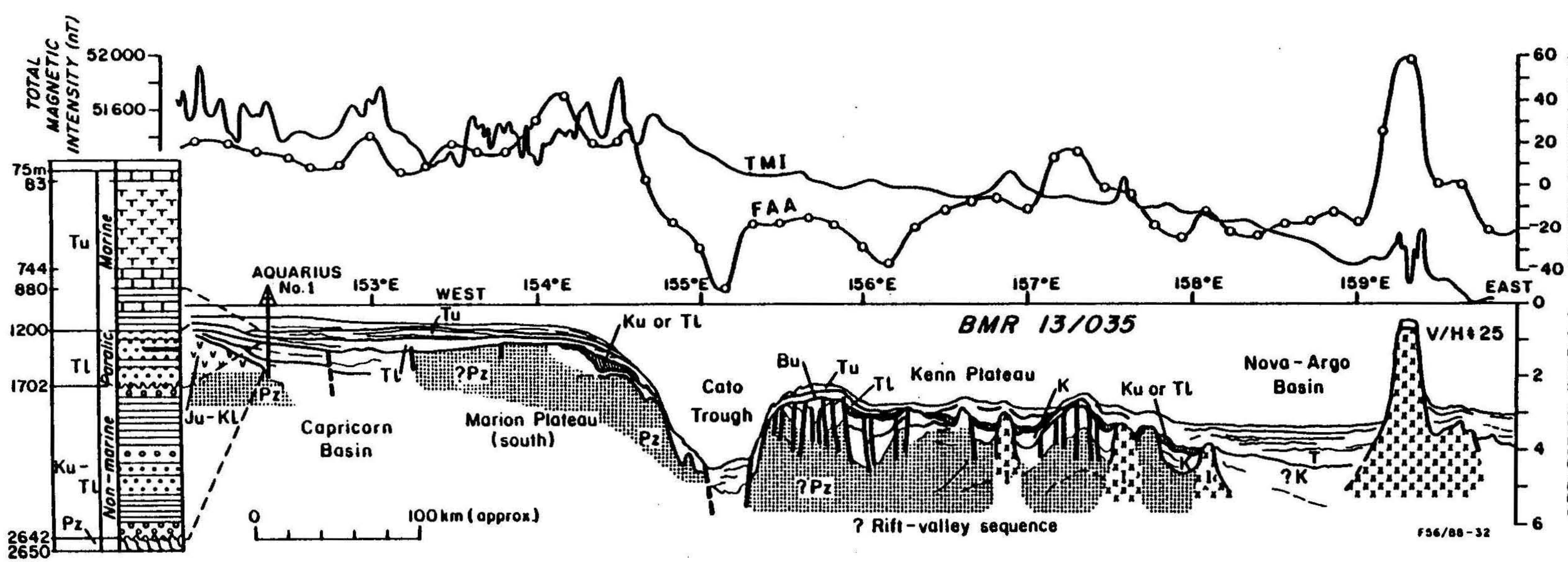


Fig. 19 Free-air gravity anomaly profiles, Fraser Island - Moreton Bay, BMR surveys 1970-73.

Fig. 20 Kenn Plateau / Capricorn Basin structure.

Transect location





Interpretation of BMR seismic profile over southern extremity of Marion Plateau and Kenn Plateau, tied to Aquarius 1 (Gulf, 1968) in Capricorn basin. Also shows free-air gravity (FAA) and total magnetic intensity (TMI) profiles. Depositional environments in Aquarius 1 are indicated. Rift-stage sediments appear to be present in depocenter on eastern flank of Marion Plateau and on Kenn Plateau.

(from Willcox, 1981; Gulf, 1968 ref. - Carlsen & Wilson, 1968a)

QUEENSLAND

GREAT BARRIER REEF REGION
AUSTRALIA

SCALE 1:5 000 000

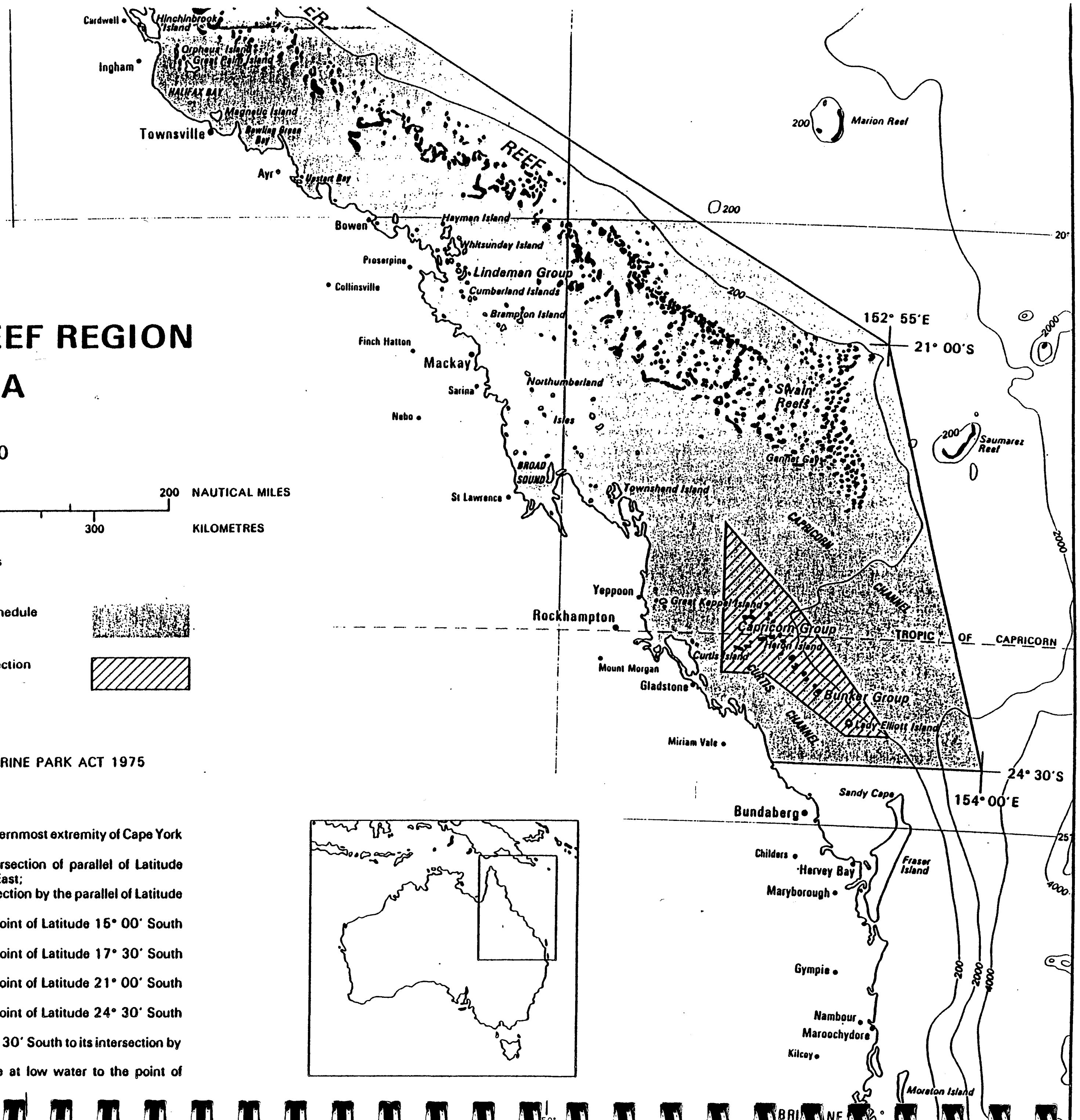
NAUTICAL MILES 50 0 100 200 NAUTICAL MILES

KILOMETRES 50 0 100 200 300 KILOMETRES

Bathymetric contours in metres

Area of the Great Barrier Reef Region described in the schedule to the Great Barrier Reef Marine Park Act, 1975.

The Great Barrier Reef Marine Park — Capricornia Section Proclaimed — 17 October 1979



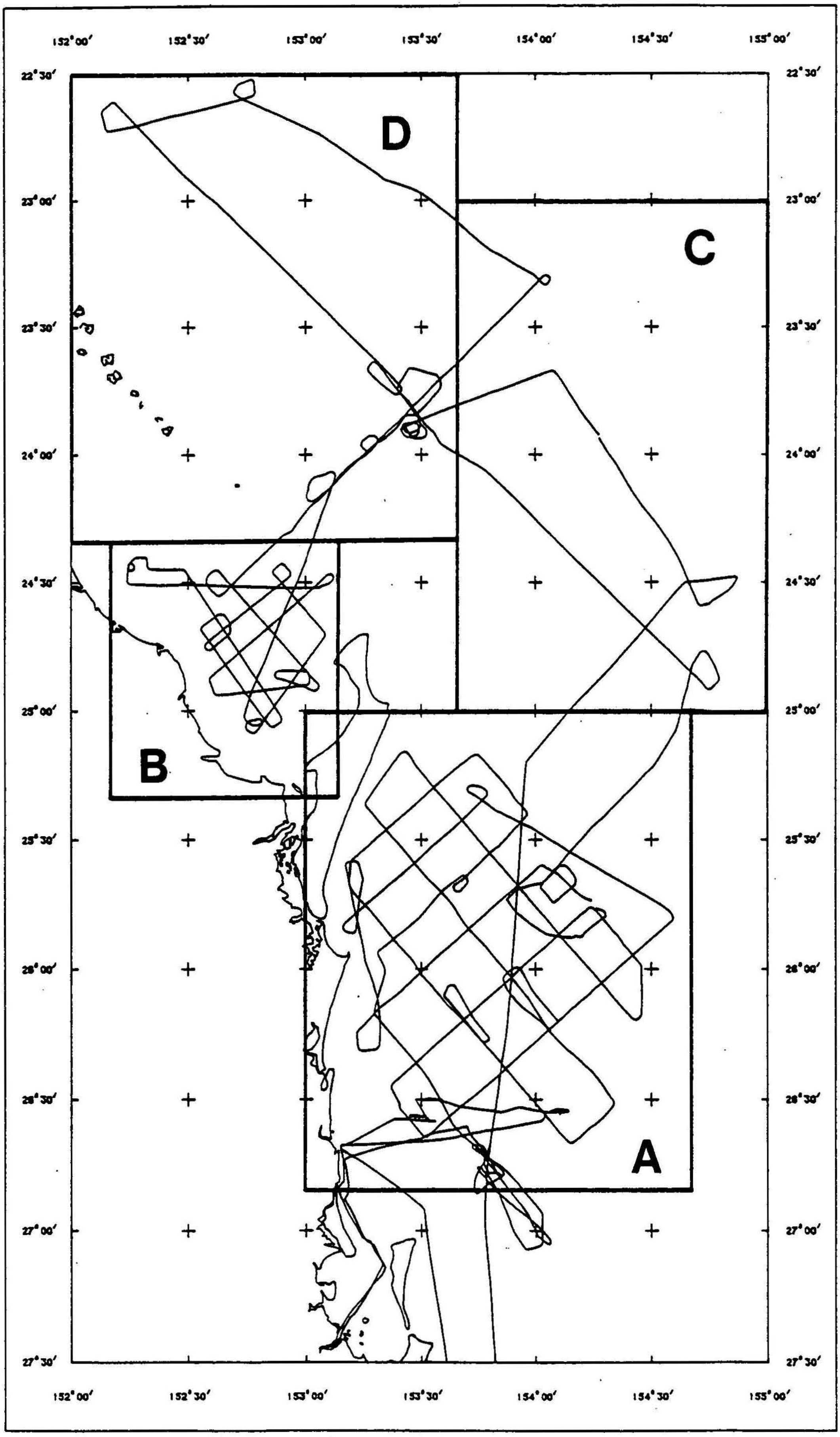
SCHEDULE TO THE GREAT BARRIER REEF MARINE PARK ACT 1975
(AS AMENDED 1978)

The area the boundary of which—

(a) commences at the point that, at low water, is the northernmost extremity of Cape York Peninsula Queensland;
(b) runs thence easterly along the geodesic to the intersection of parallel of Latitude 10° 41' South with meridian of Longitude 145° 00' East;
(c) runs thence southerly along that meridian to its intersection by the parallel of Latitude 13° 00' South;
(d) runs thence south-easterly along the geodesic to a point of Latitude 15° 00' South Longitude 146° 00' East;
(e) runs thence south-easterly along the geodesic to a point of Latitude 17° 30' South Longitude 147° 00' East;
(f) runs thence south-easterly along the geodesic to a point of Latitude 21° 00' South Longitude 152° 55' East;
(g) runs thence south-easterly along the geodesic to a point of Latitude 24° 30' South Longitude 154° 00' East;
(h) runs thence westerly along the parallel of Latitude 24° 30' South to its intersection by the coastline of Queensland at low water; and
(j) runs thence generally northerly along that coastline at low water to the point of commencement.

Fig. 21 GBR Marine Park boundaries near survey are

SCALE 1:2500000



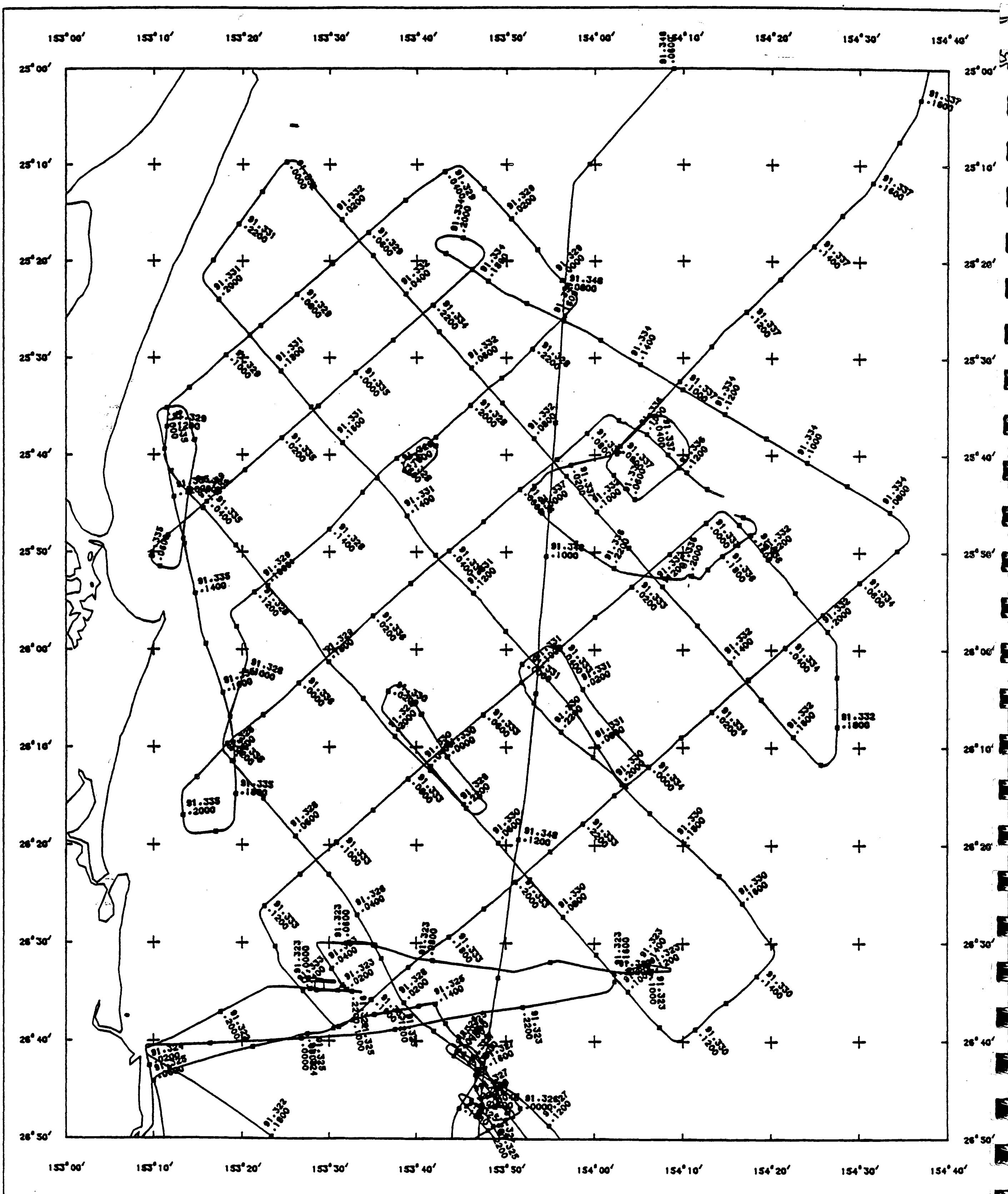
AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT
AT LATITUDE 25 00

Fig. 22 Survey 91 track map, with areas A, B, C & D marked.

SHIPS TRACKS AREA A

SCALE 1:1000000

ss.ddd ss = survey no. (91) ddd = Julian day
.hhmm hhmm = GMT

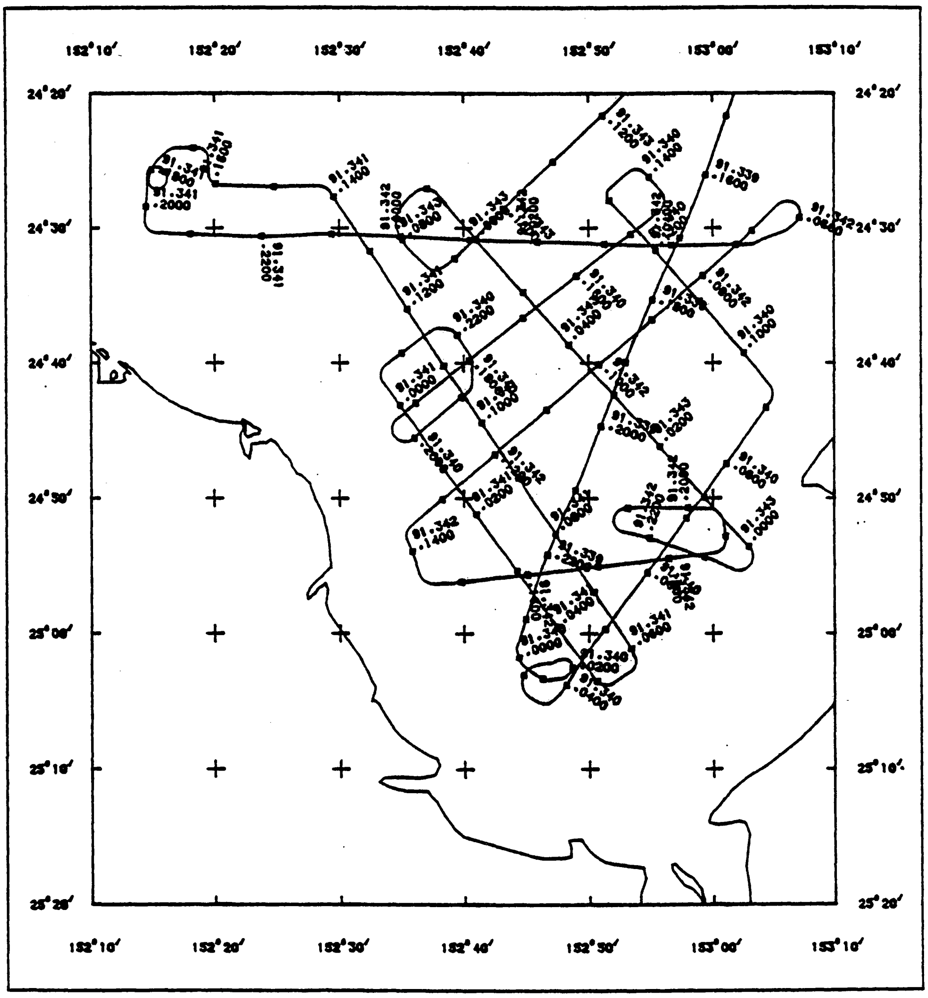


AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT
AT LATITUDE 25 00

Fig. 23 Time-annotated track map, area A (SE of Fraser I.)

SHIPS TRACKS AREA B

SCALE 1:1000000



UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT
AT LATITUDE 25 00

ss.ddd　　ss = survey no. (91)　ddd = Julian day
.hhmm　　hhmm = GMT

Fig. 24　Time-annotated track map, area B (Hervey Bay).

SHIPS TRACKS AREA C

SCALE 1:1000000

ss.ddd ss = survey no. (91) ddd = Julian day
.hhmm hhmm = GMT

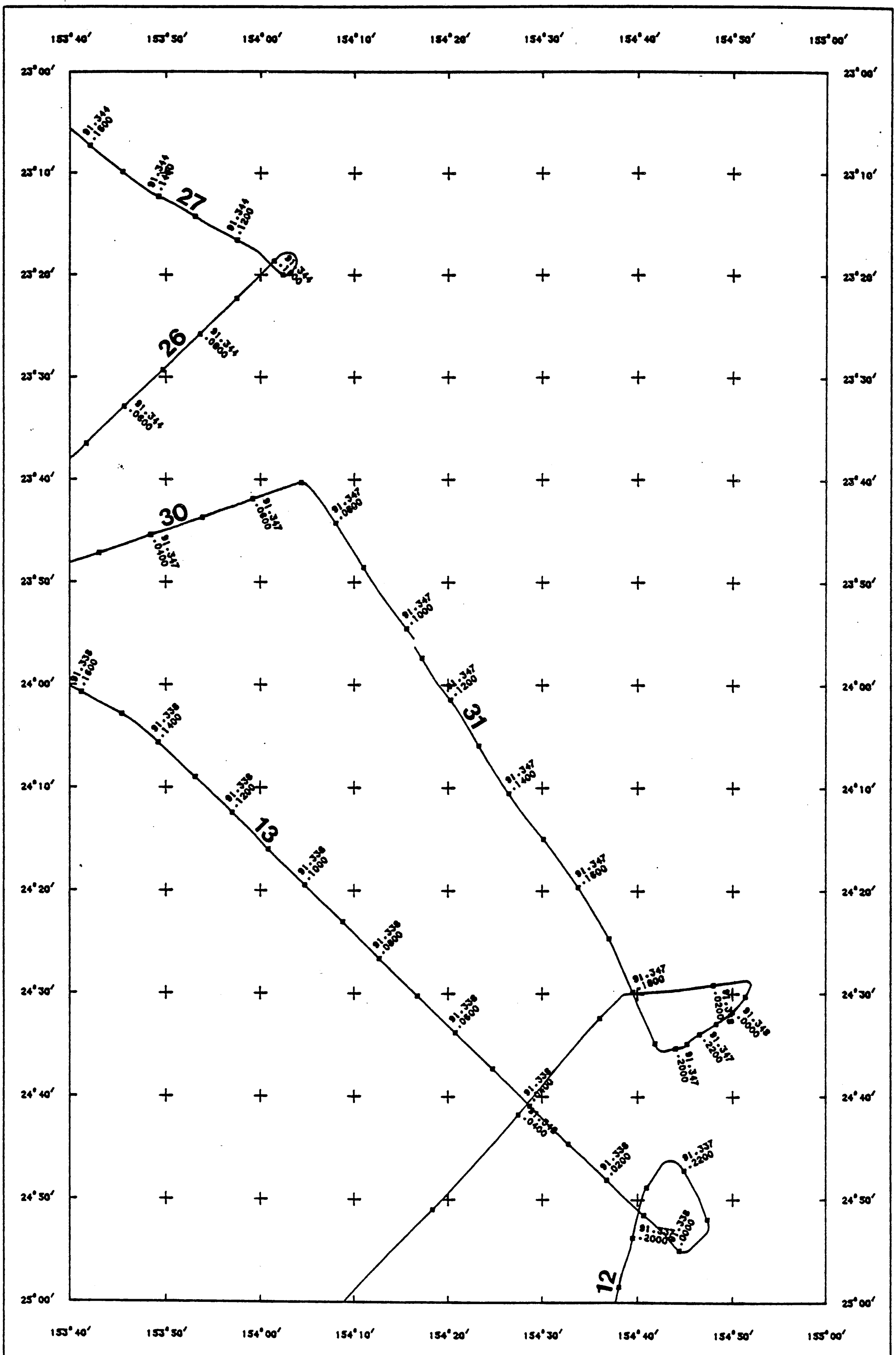


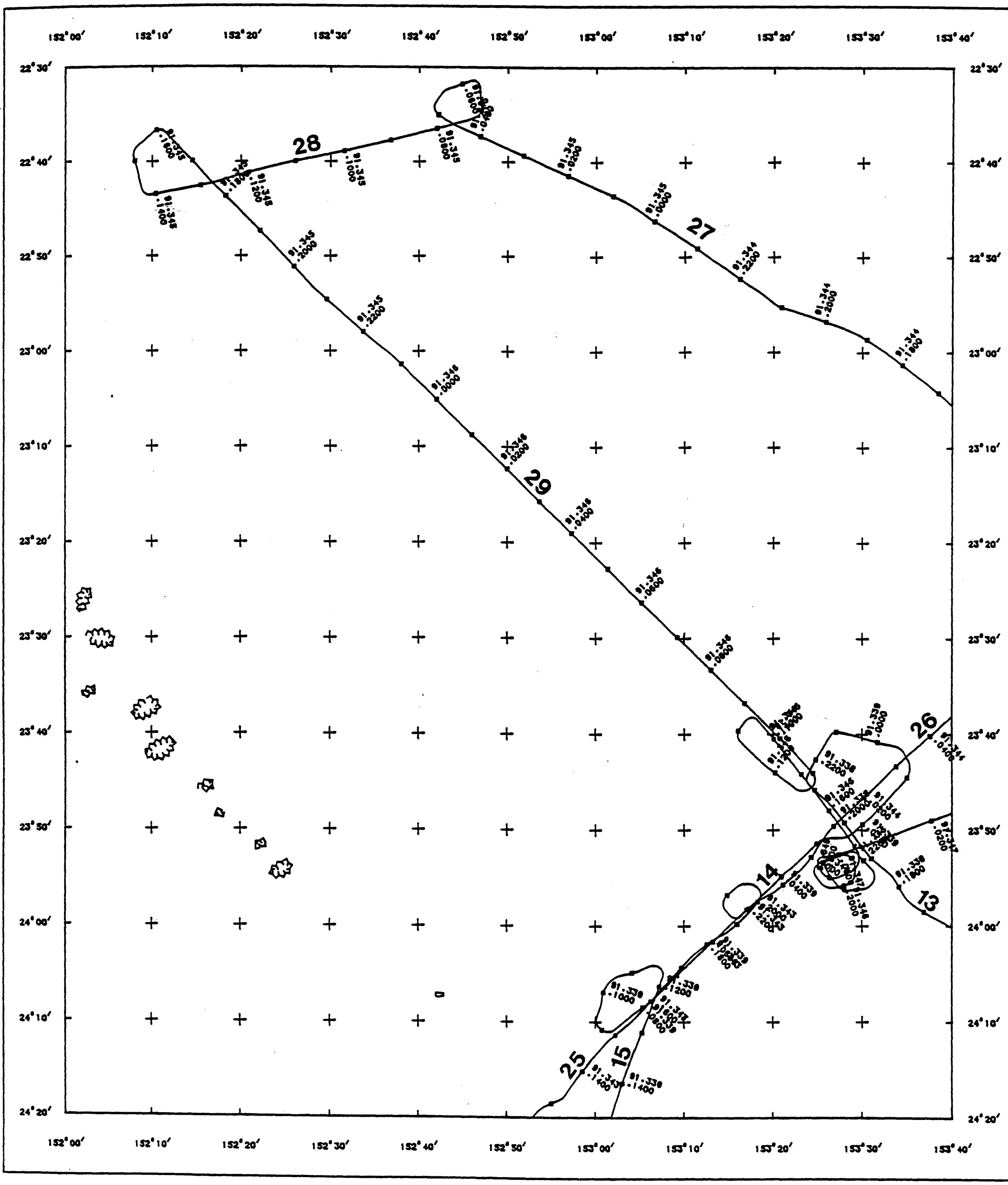
Fig. 25 Time-annotated track map, area C (northern Tasman Sea)

AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT

SHIPS TRACKS AREA D

SCALE 1:1000000

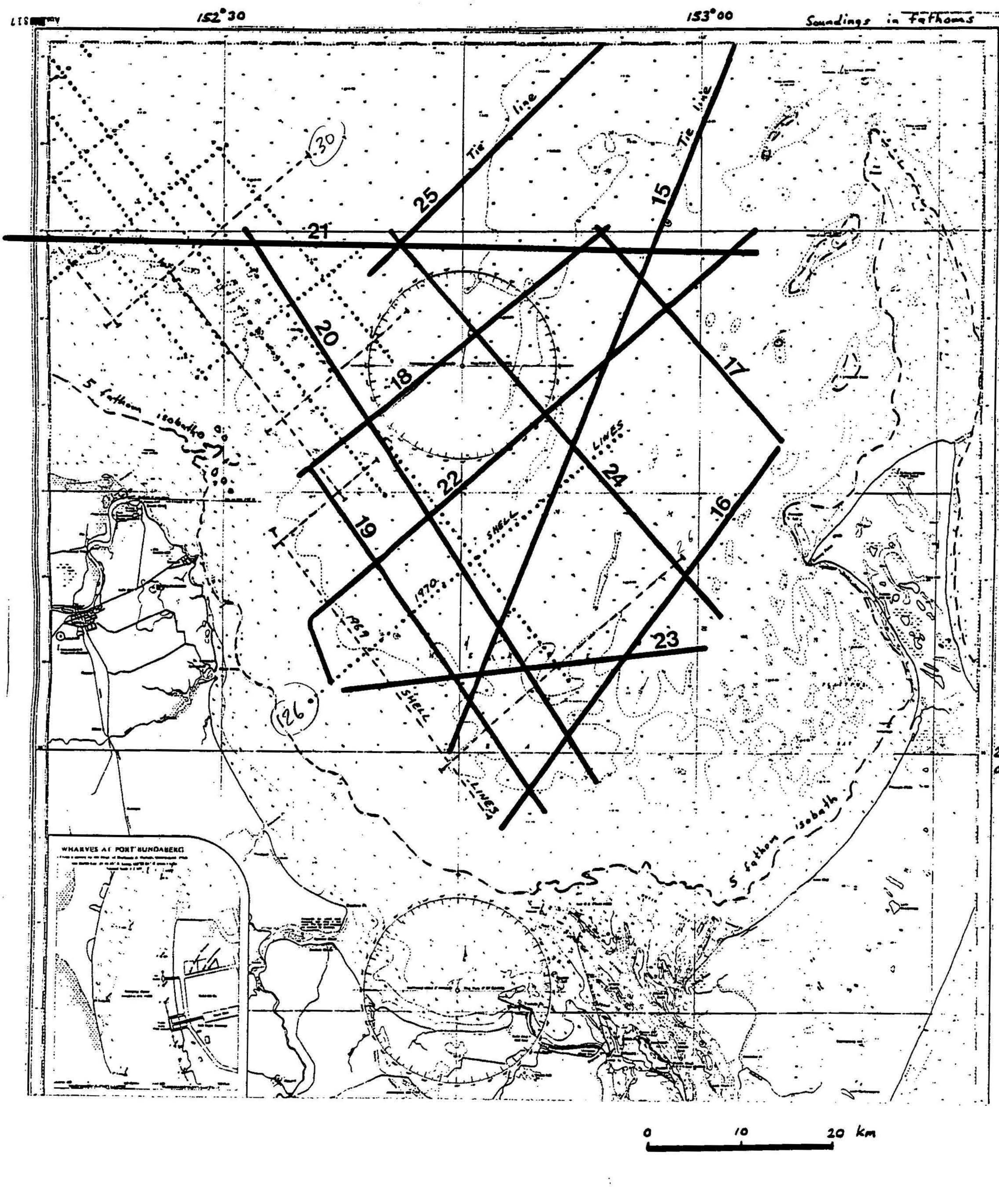
ss.ddd ss = survey no. (91) ddd = Julian day
.hhmm hhmm = GMT

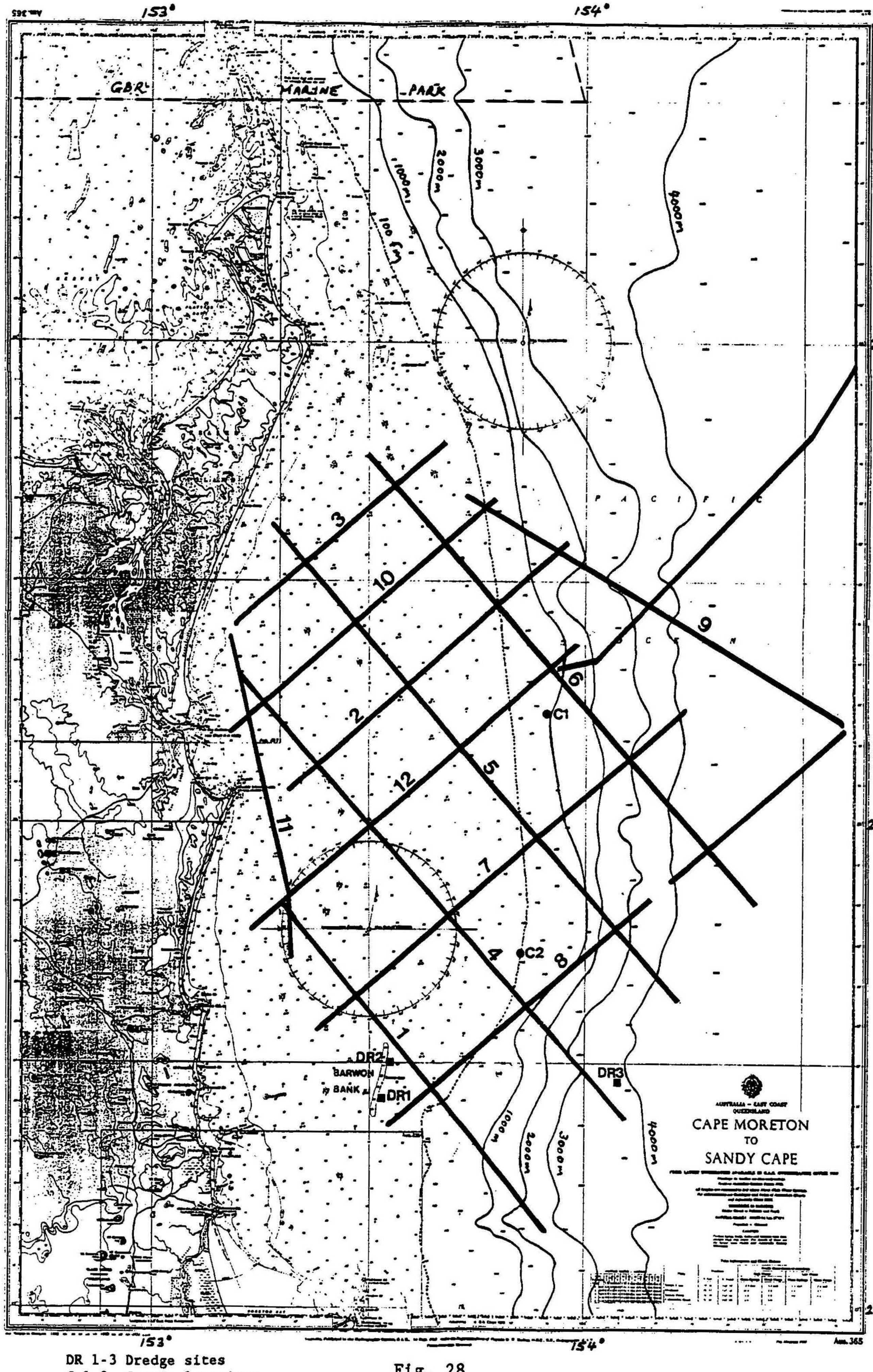


AUSTRALIAN NATIONAL SPHEROID
UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT
AT LATITUDE 25 00

Fig. 26 Time-annotated track map, area D (Capricorn Basin).

Fig. 27 Survey 91 seismic lines in Hervey Bay showing relationship to Shell 1969 & 1970 seismic grid.

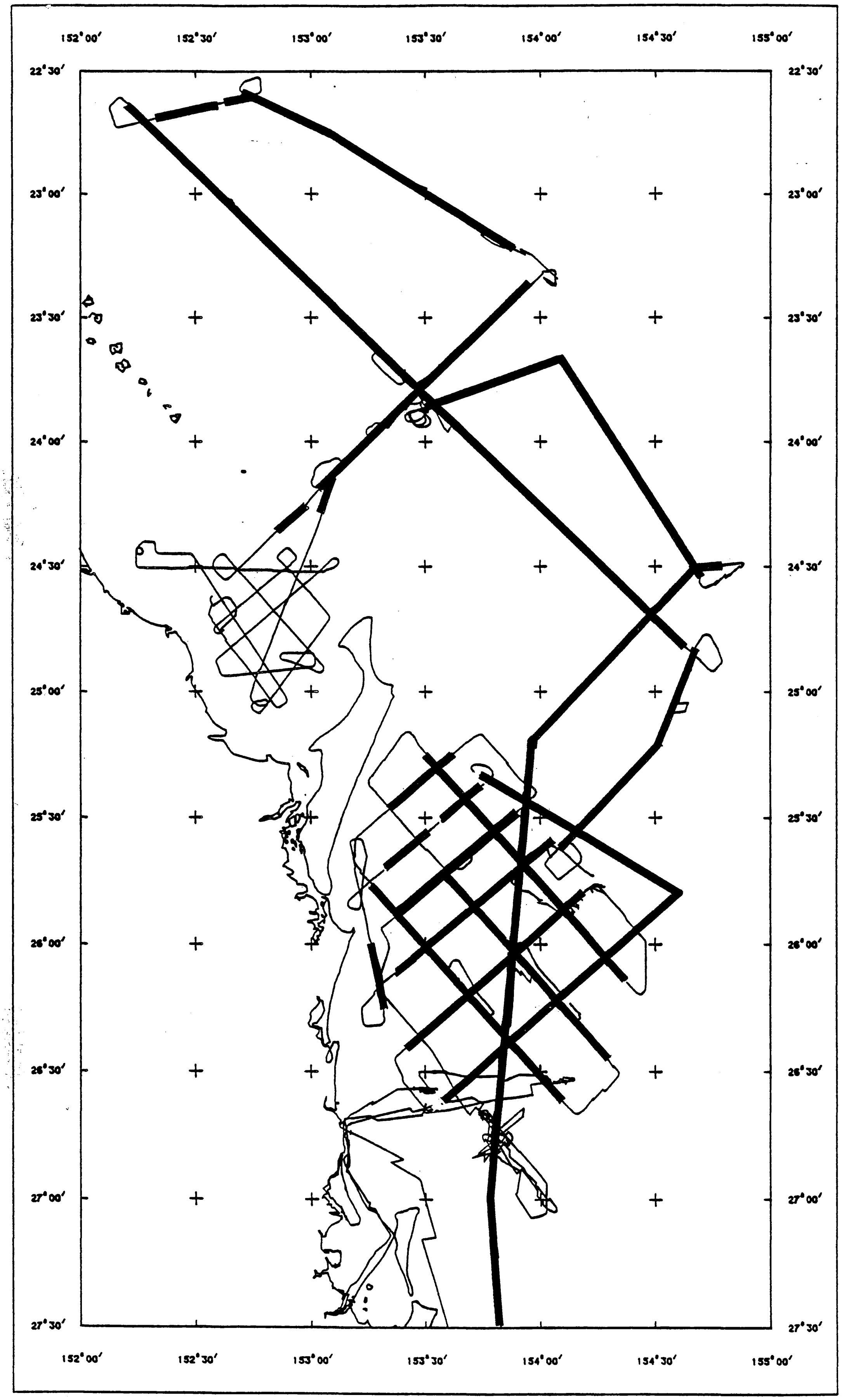




DR 1-3 Dredge sites
C 1-2 Canyon locations

Fig. 28
Survey 91 seismic lines SE of Fraser Island, bathymetry and dredge site locations.

MAGNETIC PROFILE COVERAGE



Raw navigation on base map

MARYBOROUGH/CAPRICORN

UNIVERSAL MERCATOR (SPHEROID)
WITH NATURAL SCALE CORRECT
AT LATITUDE 25 00

Fig. 29 Magnetic profile coverage achieved during Survey 91.

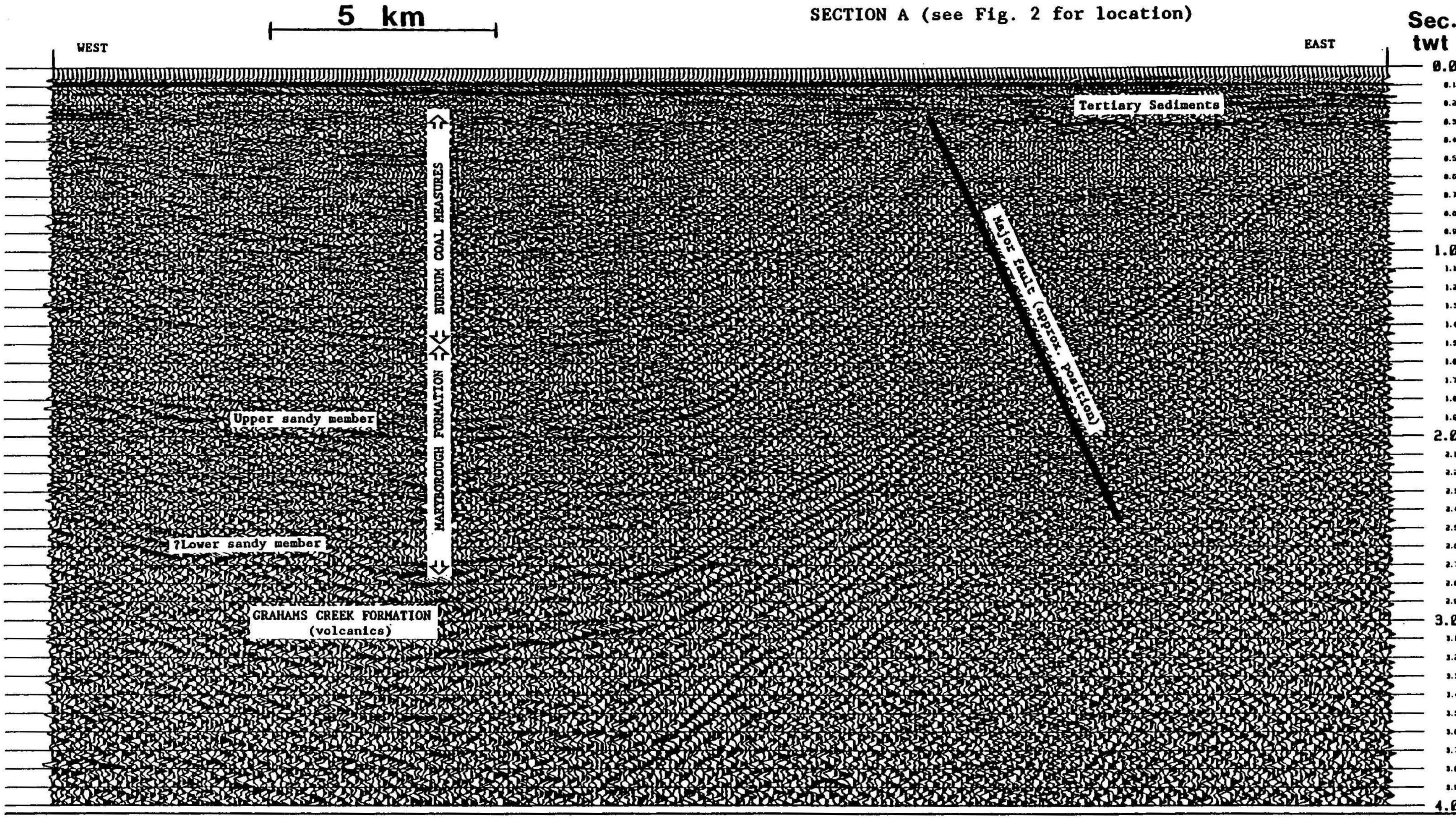


Fig. 30 Preliminary stack section and interpretation across the depocentre of the offshore Maryborough Basin in Hervey Bay (Line 91/021).

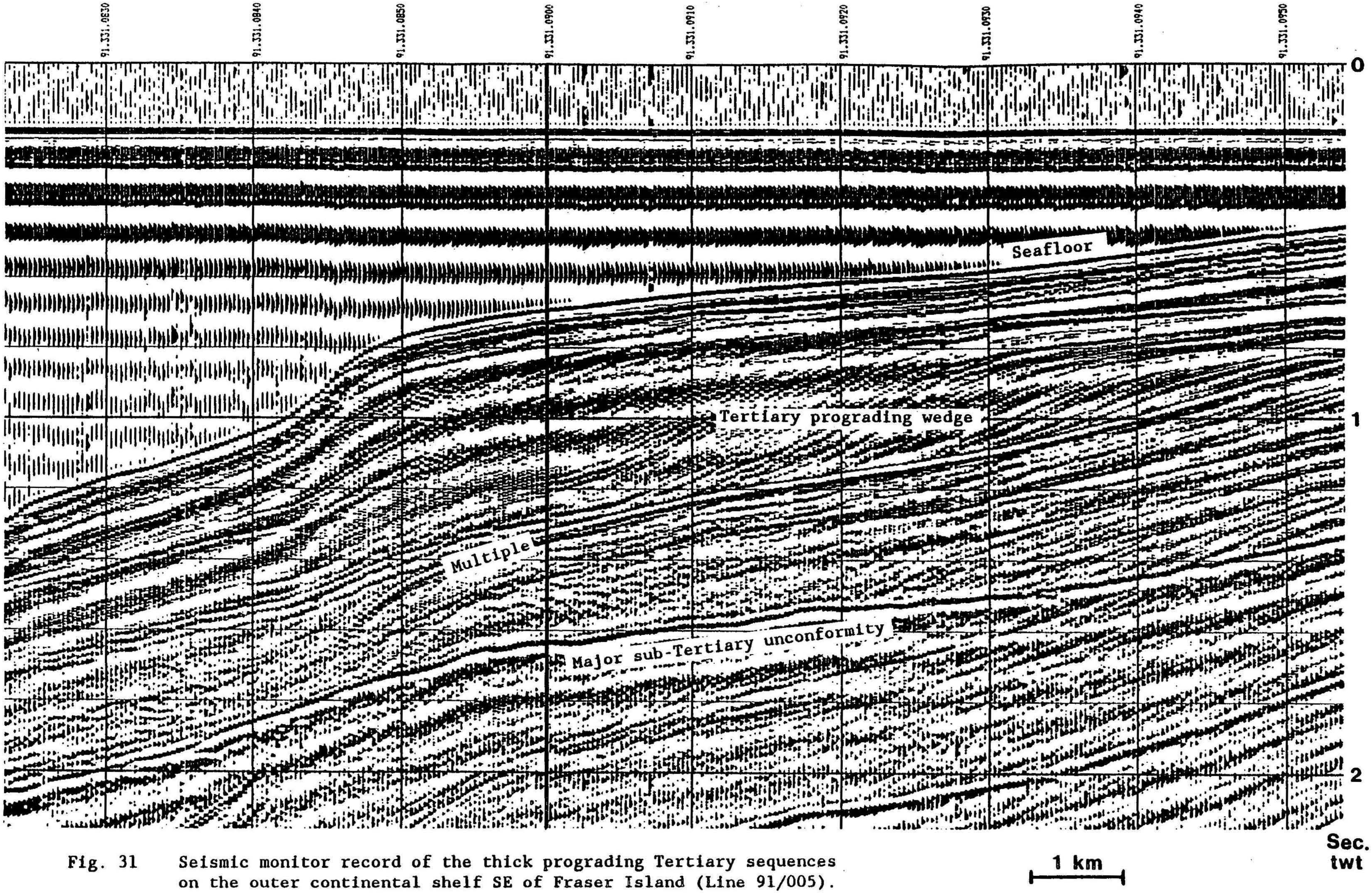


Fig. 31 Seismic monitor record of the thick prograding Tertiary sequences on the outer continental shelf SE of Fraser Island (Line 91/005).

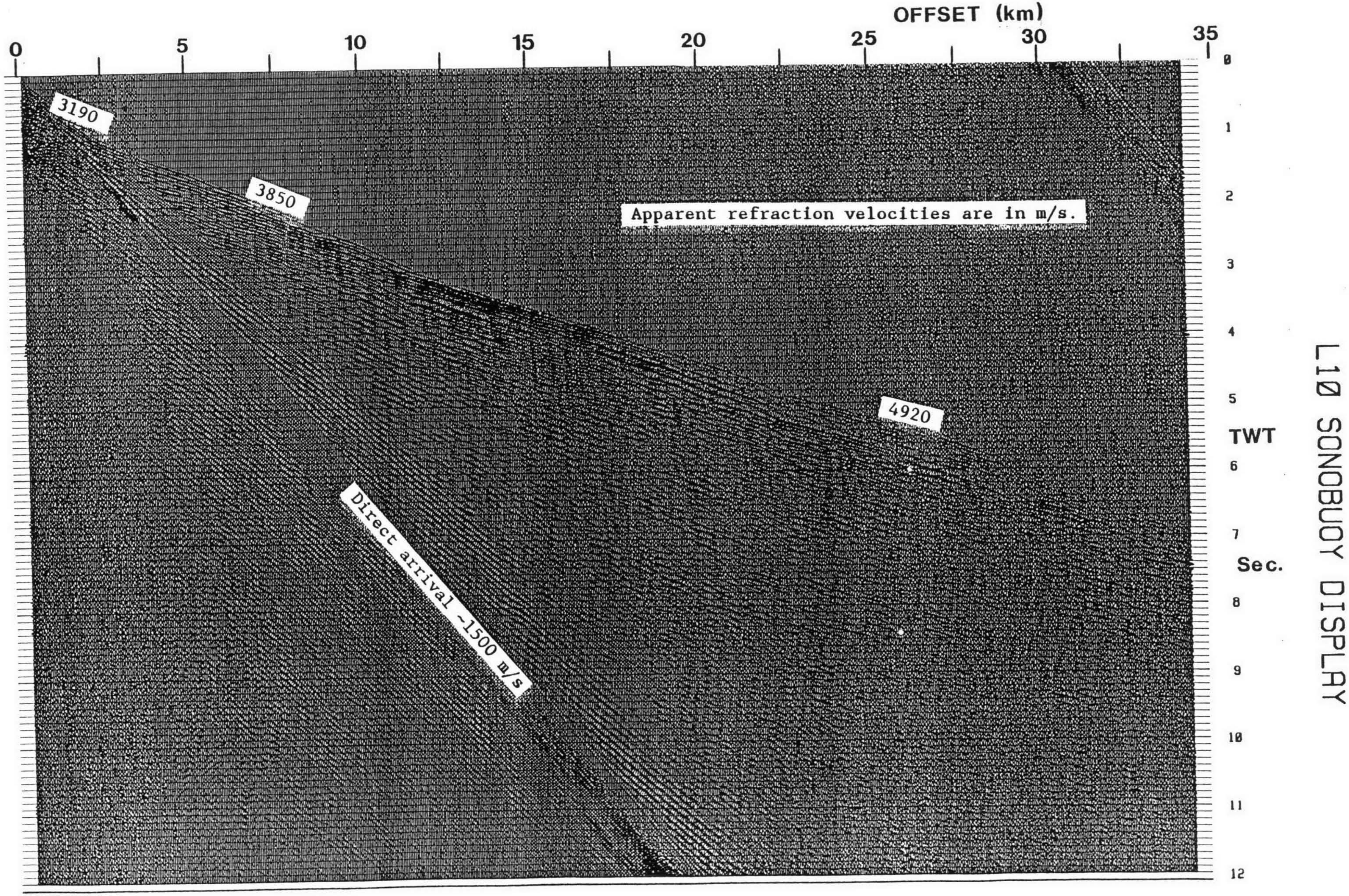


Fig. 32 Display of sonobuoy SB4 record on Line 91/010 (SE of Fraser Island).

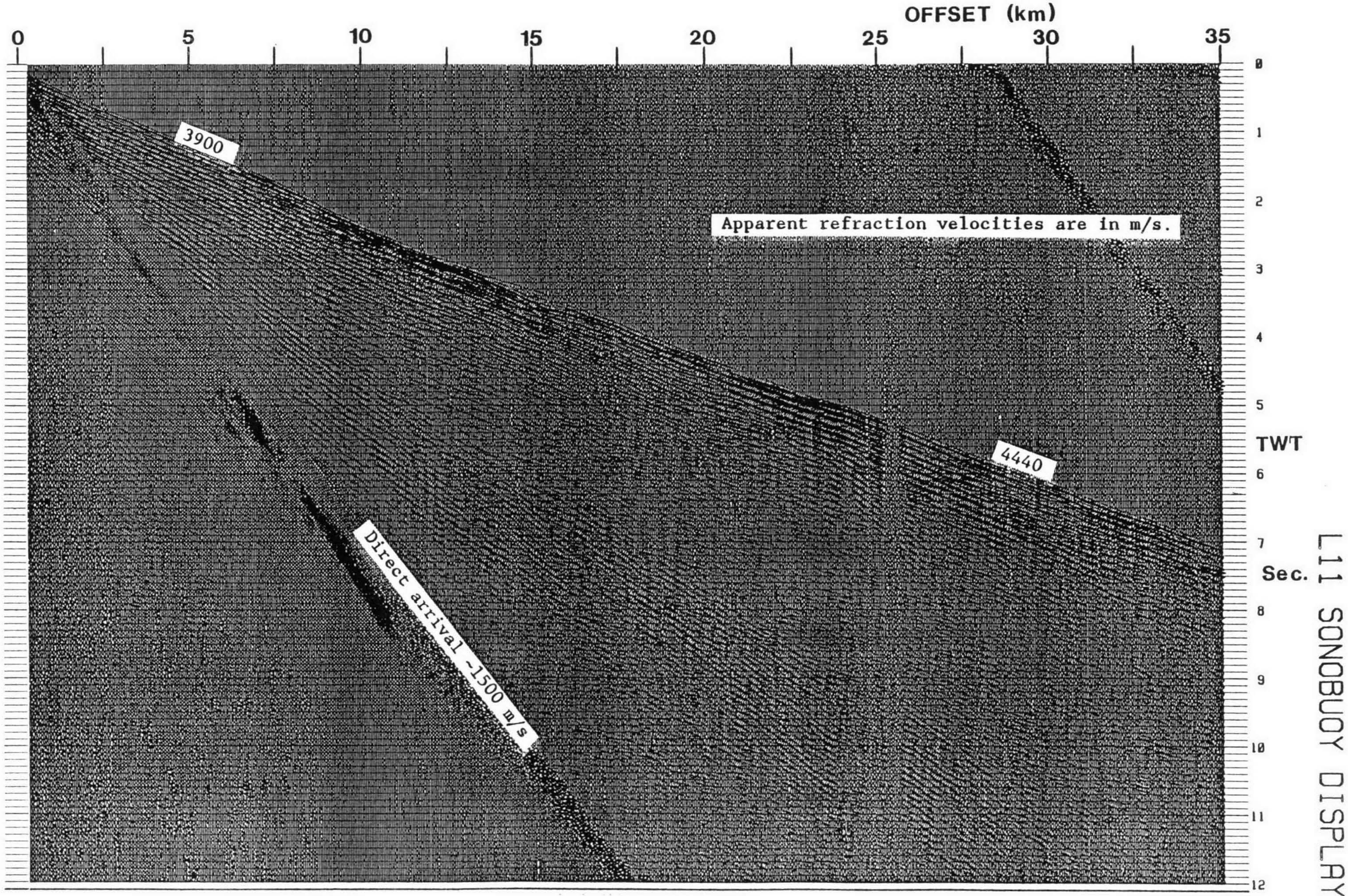


Fig. 33 Display of sonobuoy SB5 record on Line 91/011 (SE of Fraser Island).

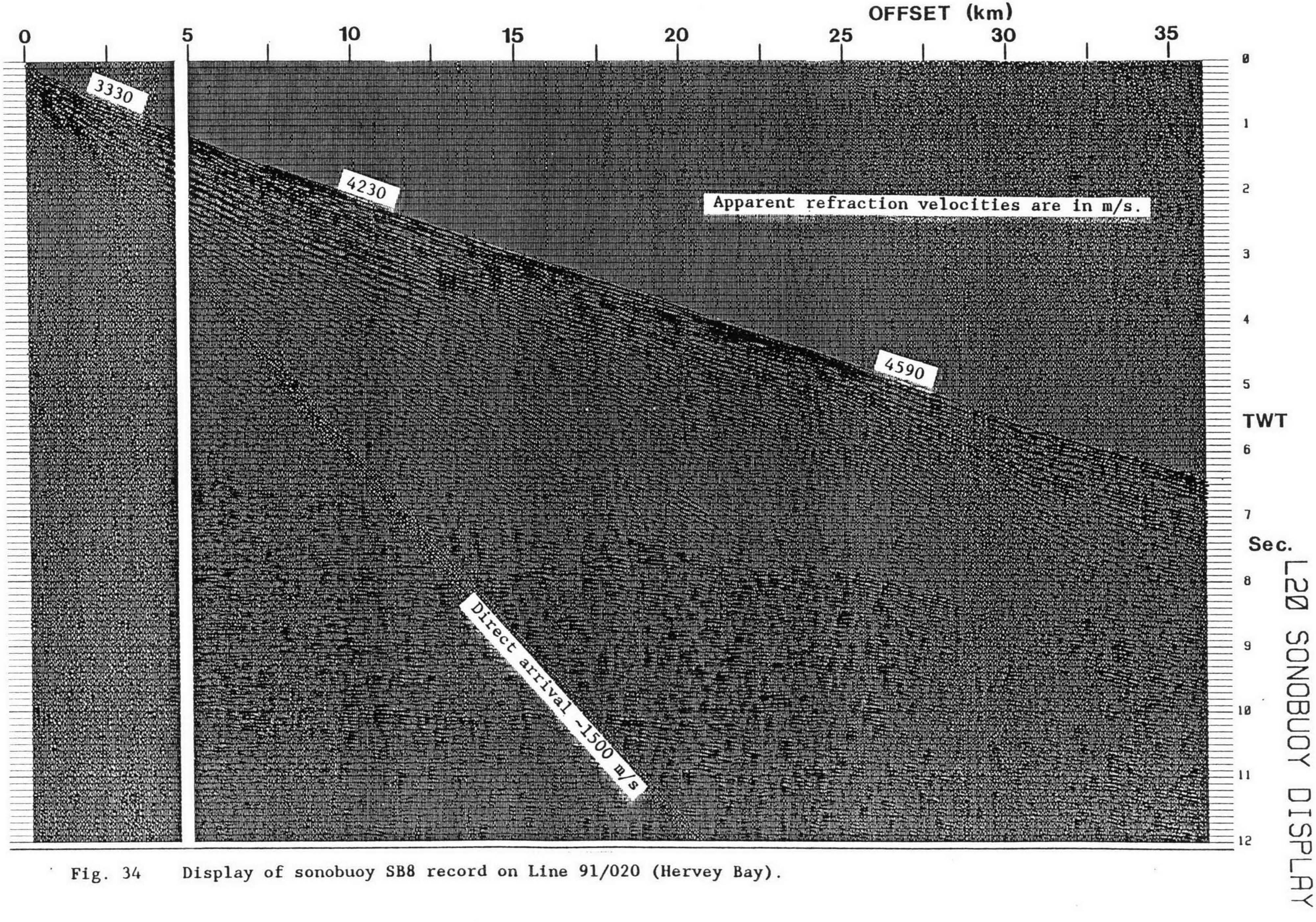


Fig. 34 Display of sonobuoy SB8 record on Line 91/020 (Hervey Bay).

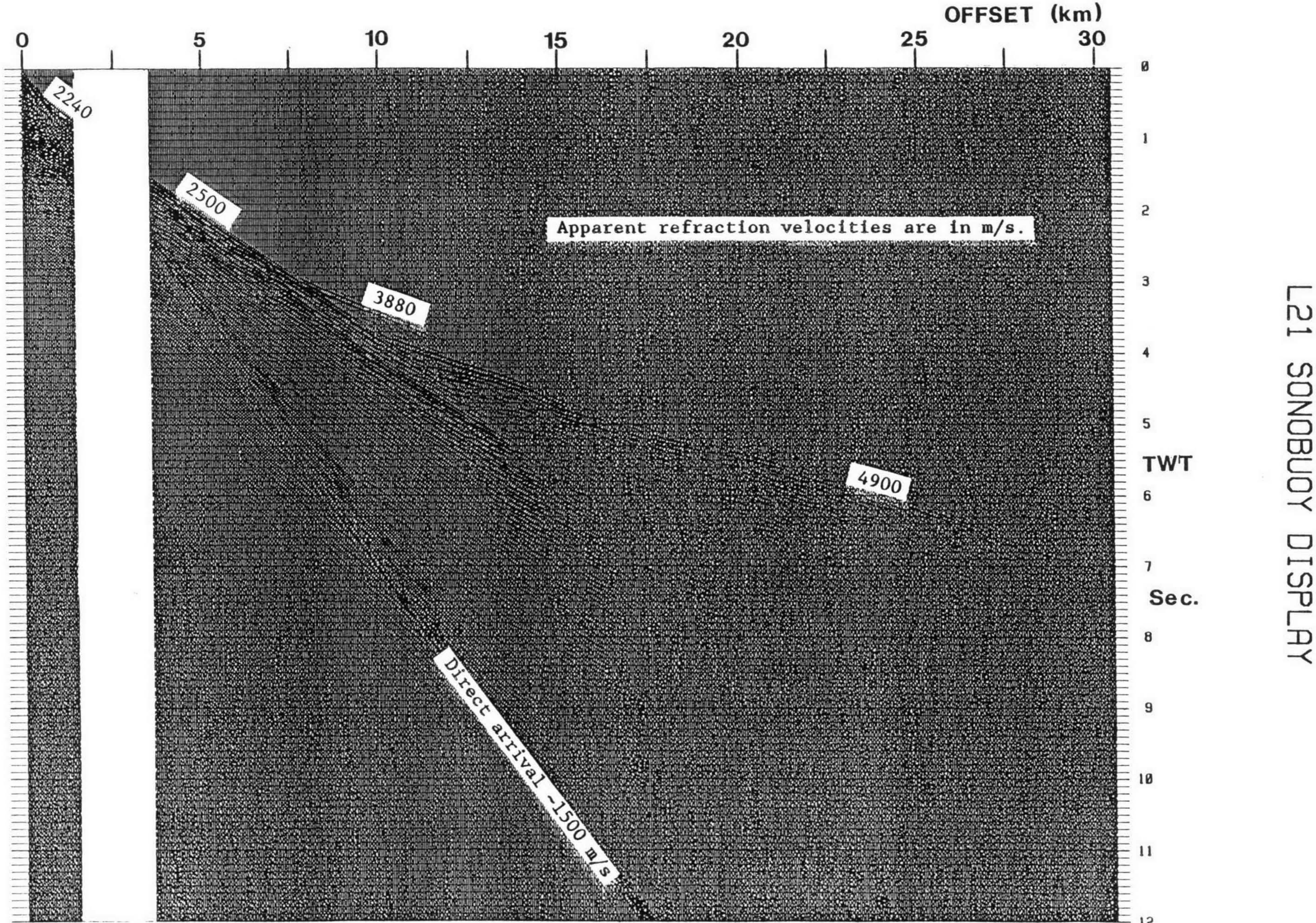


Fig. 35 Display of sonobuoy SB10 record on Line 91/021 (Hervey Bay).

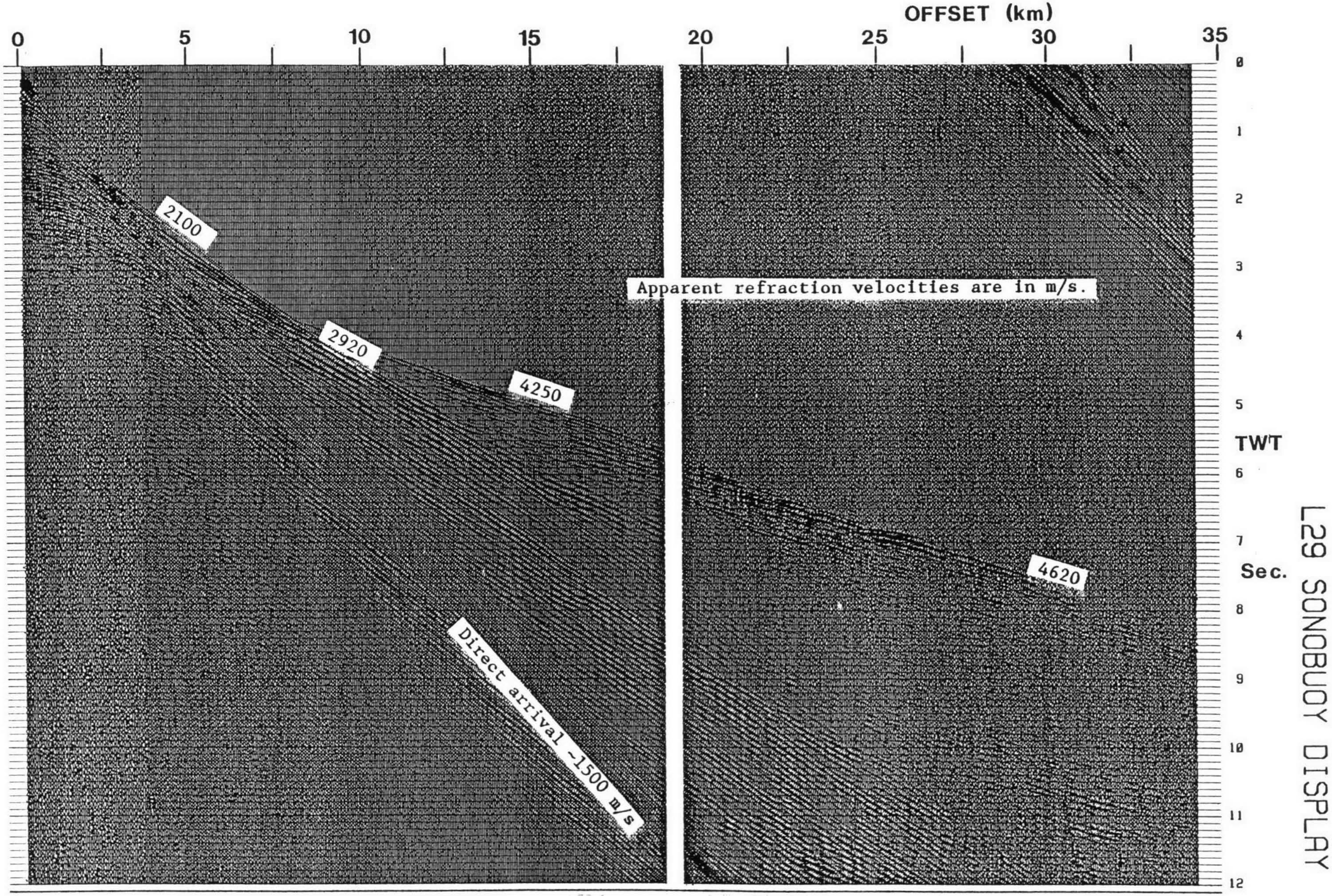


Fig. 36 Display of sonobuoy SB11 record on Line 91/029 (Capricorn Basin).

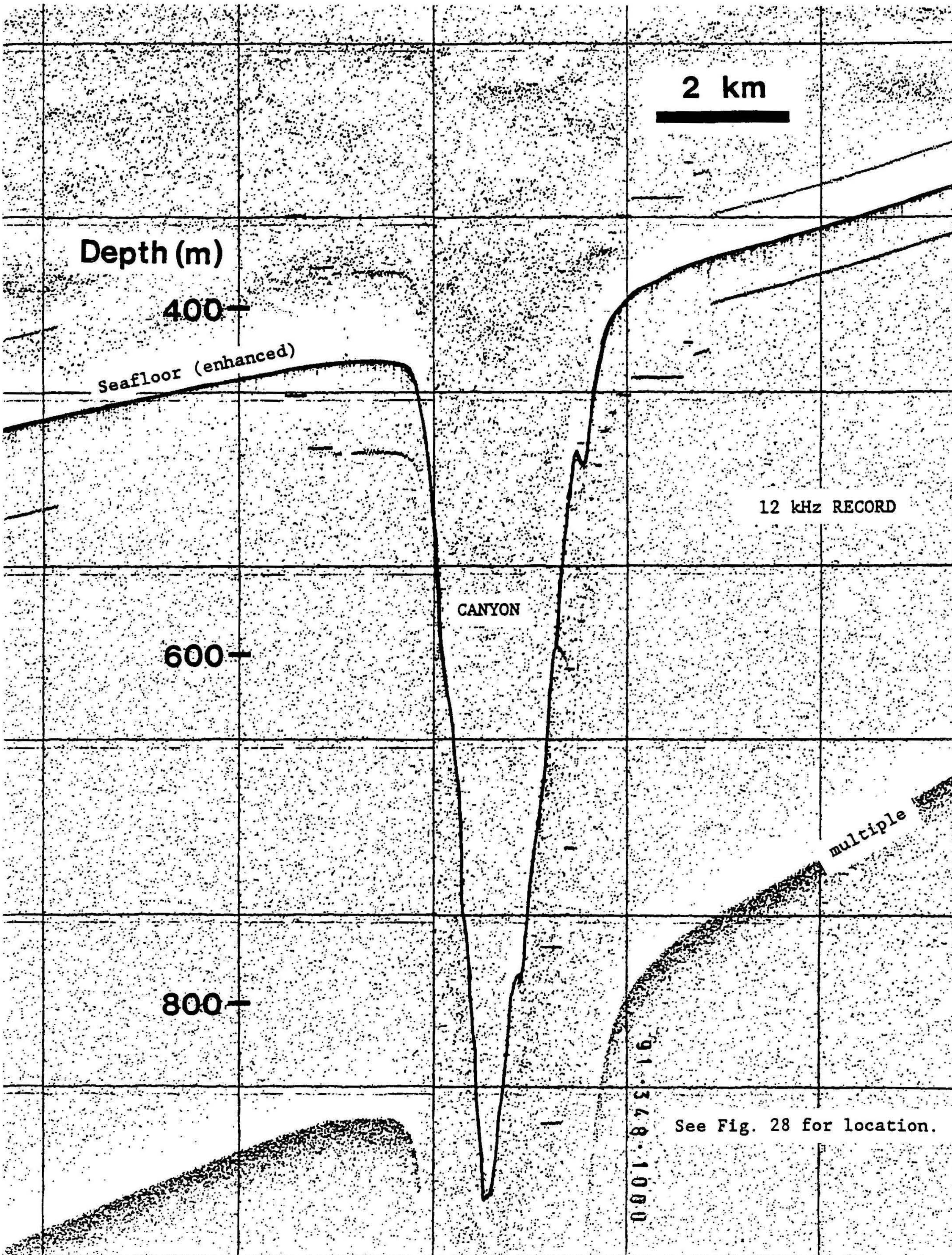


Fig. 37 Canyon development on the outer continental shelf - location C1.

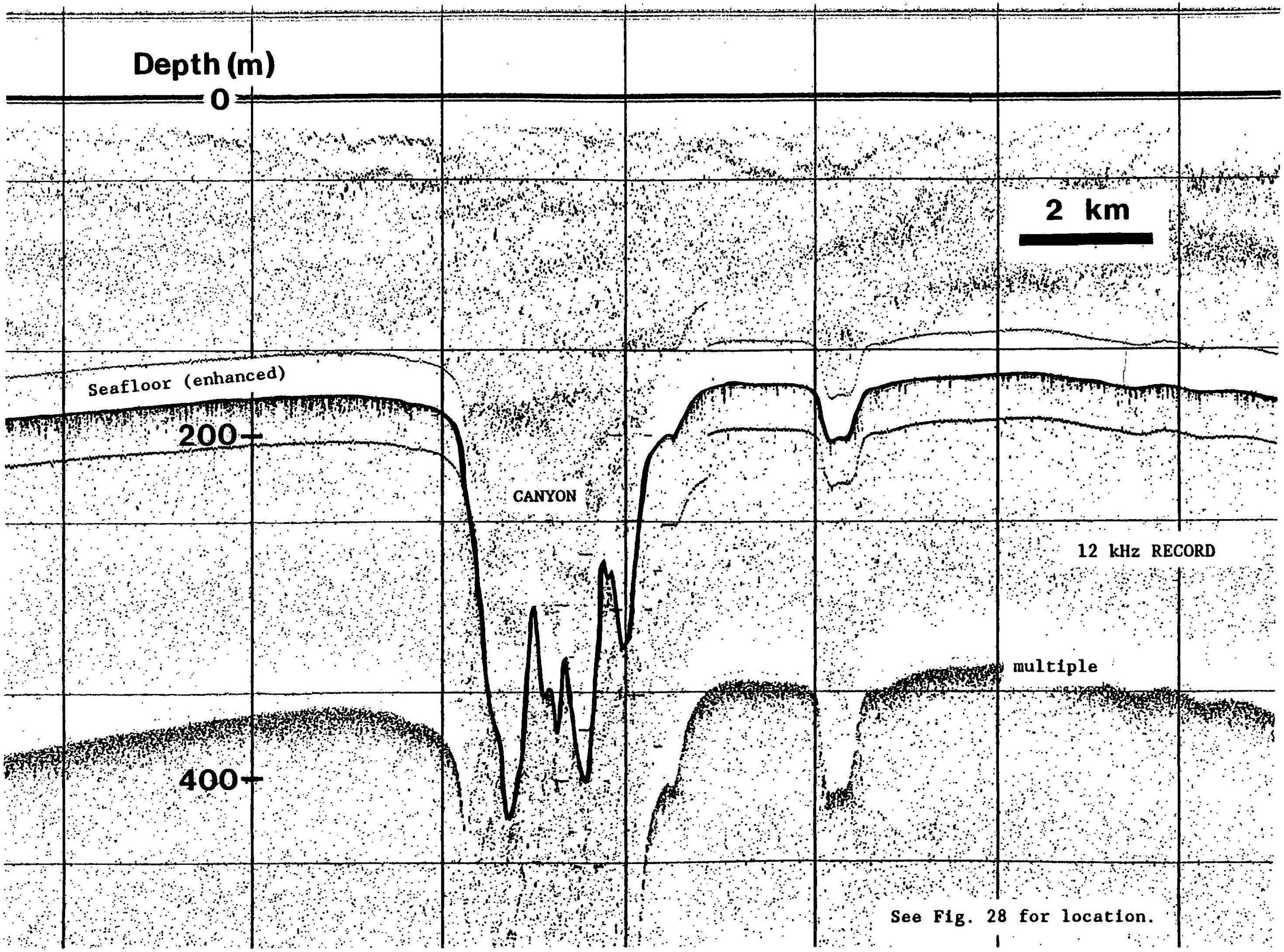


Fig. 38 Canyon development on the outer continental shelf - location C2.

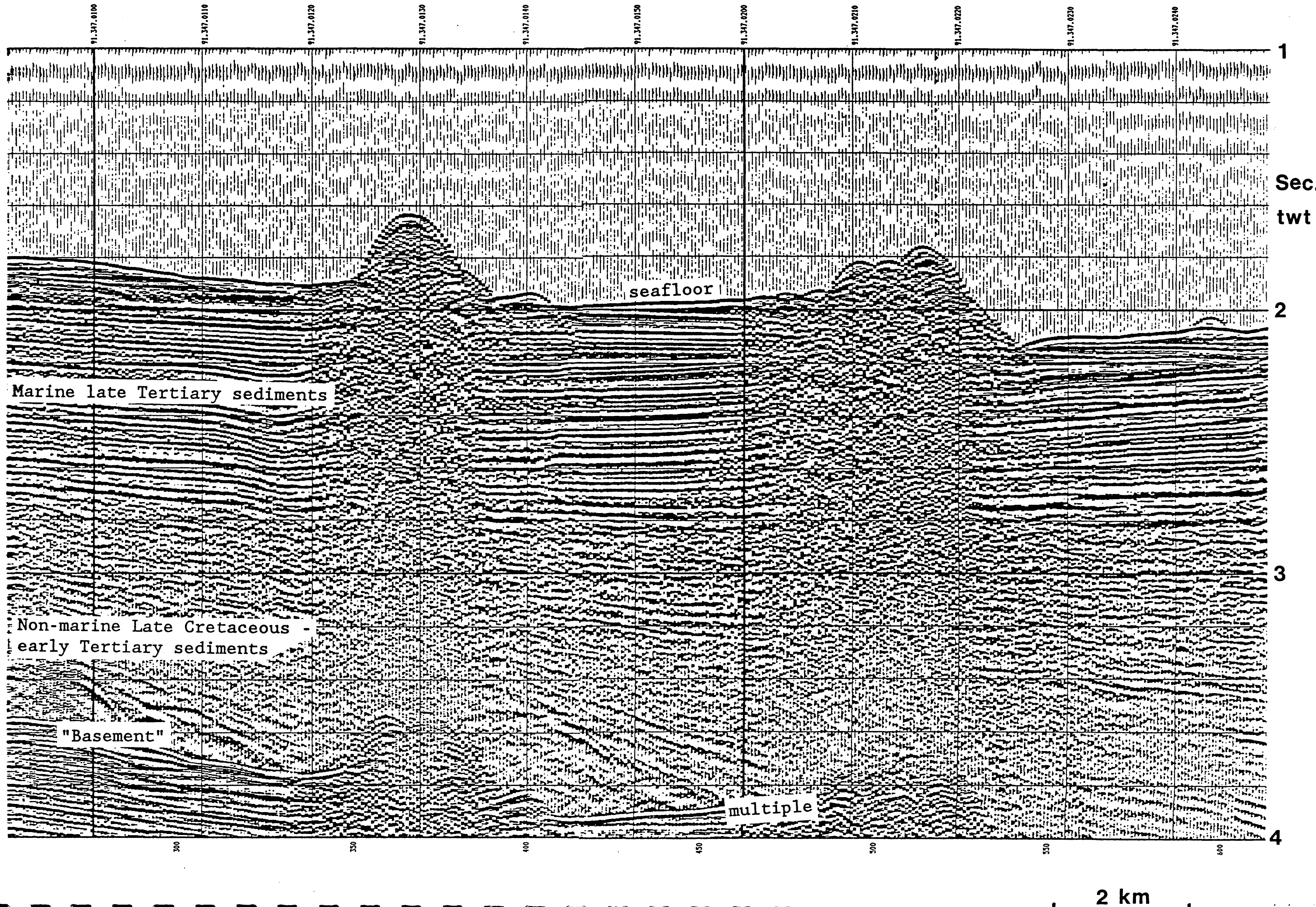


Fig. 39 Seismic monitor record of diapiric structures in the deep-water Capricorn Basin (Line 91/030).