Geology and geophysics of the offshore Maryborough, Capricorn and northern Tasman Basins: Results of AGSO Survey 91

by

P.J. Hill

RECORD 1994/1

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO

AUSTRALIAN
GEOLOGICAL SURVEY
ORGANISATION

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Marine Geoscience and Petroleum Geology Program

Project 121.21

AGSO Record 1994/1

Geology and geophysics of the offshore Maryborough, Capricorn and northern Tasman Basins: Results of AGSO Survey 91

by

P.J. Hill

© Australian Geological Survey Organisation, 1994

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Harvey Jacka

© Commonwealth of Australia

ISSN: 1039-0073
ISBN: 0 642 20396 2

This work is copyright. Apart from any fair dealings for the purposes of study, research, criticism or review, as permitted under the Copyright Act, no part may be reproduced by any process without written permission. Copyright is the responsibility of the Executive Director, Australian Geological Survey Organisation. Inquiries should be directed to the **Principal Information Officer, Australian Geological Survey Organisation, GPO Box 378, Canberra City, ACT, 2601.**

CONTENTS

Page

SUMMARY 5

INTRODUCTION 7

GEOLOGICAL SETTING 7
Regional Physiography 7
General Basin Geology 8
Stratigraphy and Depositional Environments 10
Structure 11
Tectonics 12

GEOPHYSICAL AND GEOLOGICAL SURVEYS / DRILLING 14
Present Status of Exploration 14
Previous Seismic Profiling and Exploration Drilling 14
Gravity and Magnetic Surveys 16
Onshore Stratigraphic Drilling 16
Marine Geological Sampling 17

VERTICAL TECTONICS AND THERMAL HISTORY 17

AGSO SURVEY 91 DATA 19

REGIONAL BATHYMETRY, GRAVITY AND MAGNETICS COMPILATIONS 19
Bathymetric Features 20
Qualitative Interpretation of Geopotential Fields 21
Gravity 21
Magnetics 22

SEISMIC STRATIGRAPHY 24
Maryborough Basin 24
Capricorn and Northern Tasman Basins 25

SEISMIC REFRACTION ANALYSIS 26

SEISMIC MAPPING RESULTS: DESCRIPTION AND DISCUSSION OF BASIN STRUCTURE 29
Maryborough Basin - Hervey Bay Area 29
Contour maps 29
Significance of sequence time thickness variations 31
Seismic profiles 31
Continental Shelf Southeast of Fraser Island (Maryborough / Northern Capricorn Basins) 33
Contour maps 34

© Australian Geological Survey Organisation, 1994

Seismic profiles 34
Bedrock structure map 35
Capricorn and Northern Tasman Basins 36
Contour maps 36
Seismic profiles 38

BASEMENT STRUCTURE, CAPRICORN BASIN 42

EROSIONAL PRODUCTS OF UPLIFT 42

BASIN EVOLUTION 43
Maryborough Basin 43
Capricorn and Northern Tasman Basins 44

CONCLUSIONS 45

ACKNOWLEDGEMENTS 47

REFERENCES 48

LIST OF FIGURES

1. Basin locality map 55
2. AGSO Survey 91 multichannel seismic reflection lines and sonobuoy experiment locations 56
3. Physiography of the region, 3-D perspective display 57
4. Main structural elements of the Maryborough / Capricorn Basin region 58
5. Lithostratigraphic relationships in the Maryborough Basin 59
6. Stratigraphic correlation, Maryborough Basin wells 60
7. Capricorn 1A and Aquarius 1 geological logs and cross-correlation 61
8. Crustal structure, based on gravity modeling, across the southern Capricorn Basin and across the northern Tasman Basin 62
9. Schematic representation of the main seismic sequences (A-E) in the Capricorn Basin 63
10. Reconstruction of the eastern margin of the Australian craton at 100 Ma; relationship of the Maryborough Basin to the plate boundary at New Caledonia 64
11. Conceptual evolution of the Maryborough Basin during the Cretaceous 65
12. Paleogeographic evolution of the Capricorn / northern Tasman Basins 66

LIST OF TABLES

1. Deep exploration wells in the Maryborough and Capricorn Basins 67
2. Main seismic sequences, Capricorn Basin 68
3. Sonobuoy results and interpretation, Survey 91 69

© Australian Geological Survey Organisation, 1994

LIST OF ENCLOSURES

1. AGSO Survey 91 (RV *Rig Seismic*) time-annotated track map, offshore southeast Queensland

2. Seismic lines and bathymetry contours, offshore southeast Queensland: 1:500 000 shot-point map

3. Seismic lines, Hervey Bay area: 1:250 000 shot-point map

4. Onshore geology of the Maryborough Basin and offshore bedrock refraction data (1:250 000 map)

5. Gravity anomaly contour map of offshore and onshore southeast Queensland (1:500 000)

6. Magnetic anomaly profiles (shipboard data), offshore southeast Queensland (1:500 000)

7. Time structure map - base Cainozoic section, Hervey Bay area

8. Time structure map - horizon A (top Lower Unproductive member of Burrum Coal Measures), Hervey Bay area

9. Time structure map - horizon A1 (top Maryborough Formation), Hervey Bay area

10. Time structure map - horizon B (base Maryborough Formation), Hervey Bay area

11. Time structure map - horizon C (base sub Maryborough Formation sequence), Hervey Bay area

12. Time structure map - 'basement' horizon, Hervey Bay area

13. Lower Unproductive member of Burrum Coal Measures (horizon A-A1) time thickness, Hervey Bay area

14. Maryborough Formation (horizon A1-B) time thickness and sub Maryborough Formation sequence (horizon B-C) time thickness, Hervey Bay area

15. Structure contour map - horizon A1 (top Maryborough Formation), Hervey Bay area

16. Structure contour map - horizon B (base Maryborough Formation), Hervey Bay area

17. Time structure map - Early Oligocene unconformity, shelf southeast of Fraser Island

18. Isopach map - Late Oligocene to Recent section, shelf southeast of Fraser Island

© Australian Geological Survey Organisation, 1994

19. Time structure map - horizon TB (top sequence B, Early Oligocene unconformity), Capricorn and northern Tasman Basins

20. Time structure map - horizon TC (top sequence C, near mid Eocene), Capricorn and northern Tasman Basins

21. Time structure map - horizon BE ('basement'), Capricorn and northern Tasman Basins

22. Time thickness map - sequence A (Late Oligocene - Recent), Capricorn and northern Tasman Basins

23. Time thickness map - Late Eocene deltaic sequence, Capricorn Basin

24. Time thickness map - Eocene shallow marine / deltaic section, sequences B+C, Capricorn and northern Tasman Basins

25. Time thickness map - sequences D+E (rift-phase section, Late Cretaceous - Early Eocene), Capricorn and northern Tasman Basins

26. Time thickness map - total sedimentary section (Late Cretaceous-Cainozoic), Capricorn and northern Tasman Basins

27. Total sediment thickness map - sequences A-E (Late Cretaceous - Cainozoic), Capricorn and northern Tasman Basins

28. Maryborough Basin interpreted seismic profiles, onshore to offshore correlations - lines S-39 & M-7030, S-33 & M-7026 and S-32 & 091/23

29. Offshore Maryborough Basin (Hervey Bay) interpreted seismic profiles oriented in dip direction - lines 091/21, 091/22P1, 091/15 and 091/16

30. Trans Capricorn Basin interpreted seismic profiles - lines 091/28, GBR-47, QP-4, 091/14 and 091/26

31. Axial interpreted seismic profile (lines 091/29P1 and 091/29P2), Capricorn Basin

32. Interpreted seismic profiles at and across the southeastern margin of the Capricorn Basin - lines 091/30, 091/31 and 091/13

33. Interpreted seismic profiles across the continental shelf southeast of Fraser Island - parts of lines 091/03, 091/05P2, 091/10 and 091/11

34. Bedrock structure beneath the continental shelf southeast of Fraser Island.

© Australian Geological Survey Organisation, 1994

SUMMARY

The Australian Geological Survey Organisation (AGSO) completed a major marine multichannel seismic (MCS) reflection survey off southeast Queensland in December 1989 using RV *Rig Seismic*. The research cruise (AGSO Survey 91) was designed to investigate the structure, stratigraphy and evolution of offshore basins along this sector of the Australian continental margin. About half of the 2900 km of seismic data collected was recorded over the offshore Maryborough Basin; the remainder was collected over the Capricorn Basin and margins of the northern Tasman Basin. The survey included seismic ties to the only deep offshore wells in the region, Aquarius 1 and Capricorn 1A located in the northern Capricorn Basin. It was the first MCS survey shot in the region since 1974. Sonobuoy refraction, gravity, magnetic and bathymetric data were also collected.

The Maryborough Basin developed in the earliest Triassic - mid Jurassic as an epicratonic downwarp, probably a foreland depression. Neocomian volcanism and rifting, perhaps generated by transtensional movements, led to a second phase of deposition that produced thick clastic shallow marine and deltaic sequences. Subsequent basin inversion in the mid Cretaceous produced major folding along northwest/NNW axes as well as normal and reverse faulting. Peneplanation following uplift has eroded up to several kilometres of section from the basin, leaving it as a remanent basin. The main causes of the uplift are believed to be (i) the mid Cretaceous deformation episode, (ii) rift flank uplift as the adjacent northern Tasman Sea opened (~63 Ma ago), and (iii) rise of the Eastern Highlands in the Late Cretaceous - Cainozoic due to crustal underplating associated with detachment faulting and transit over mantle plumes.

Up to 5 km of the Early Cretaceous Maryborough Formation (shallow marine clastics) and Burrum Coal Measures are preserved in a NNW-trending syncline beneath the western side of Hervey Bay, just off the coast northeast of Bundaberg. Depth to basement may be as much as 9-10 km. No major anticlines in the Early Cretaceous units are present beneath Hervey Bay. However, small culminations may exist in the more flat-lying strata of the basin deep northeast of Bundaberg.

Reinterpretation of onshore seismic data in the Maryborough Basin has provided new insight into the structural configuration of this part of the basin.

Survey 91 established that the Maryborough Basin does extend beneath the continental shelf southeast of Fraser Island. The section is folded and faulted, with broad anticlinal structures present. Seismic data quality in the Cretaceous and older section is poor in this area, perhaps a consequence low acoustic impedance contrast (?tight formations). Much of the shelf is underlain by about 2.0 s twt (~4 km) of Maryborough Basin section. A major syncline in Wide Bay contains up to 5 km of Early Cretaceous sediments. Basement here may lie at 8-9 km depth.

The Capricorn and northern Tasman Basins are adjoining basins that were initiated by the Cretaceous episode of rifting and subsequent breakup of the eastern Australian craton. While the Tasman opened to become an oceanic basin, the Capricorn Basin remained as a continental failed rift separated from the Tasman Basin by the Cato Fracture Zone (transform fault). The continental crust, on which the Capricorn Basin is founded, has

© Australian Geological Survey Organisation, 1994

undergone relatively minor extension. Though basement structures generally follow a northerly to northwest trend, the structural pattern is complex resulting in a mainly discontinuous series of rift basins of varying geometry. Complex structure is also indicated by gravity mapping. Complex basement structure may be due to early (?Early-mid Cretaceous) wrench movements. The basement structures thus created probably controlled Late Cretaceous - early Tertiary northeast-southwest extension. Shallow-dipping intra-'basement' horizons that are particularly evident beneath the central and southern parts of the basin may be fault-plane reflections from deep extensional structures (perhaps reactivated thrusts), but could also be indicative of large wedges of old (Cretaceous and older) sediment or volcaniclastics.

Sedimentation in the Capricorn Basin began with continental rift-fill, but became progressively more marine as the basin subsided. Five major seismic sequences have been identified and mapped. In the deep-water southeastern part of the basin, up to 3.7 s twt (about 5.7 km) of Late Cretaceous - Paleogene section is associated with major half-graben development. A mid Eocene compressional or transpressional event has reactivated basement structures and produced minor faulting and folding in the section. The event, which also produced significant uplift and subsequent erosion, is attributed to intraplate stress resulting from major global plate reorganization that occurred at about 43 Ma.

Volcanism, perhaps hotspot related, was active in the southern Capricorn Basin during Late Oligocene. Volcanic edifices several hundred metres high and 3-5 km across are exposed on the seafloor. Volcanics, probably basaltic dykes and sills, are also evident in the pre-Miocene section of the thick post-breakup deposits at the base of the continental slope east of Fraser Island and at the northern Tasman transform margin (Cato Fracture Zone).

In the northern Tasman Basin, about 3.5 km of Cainozoic post-breakup sediments were deposited at the base of the continental slopes, to the east and southeast of Fraser Island and also at abyssal depths along the northern transform margin. The section thins to about 2 km towards the middle of the basin. The steep and rugged marginal slopes have been sites of large-scale mass movements, including rotational slumping and submarine landsliding. Large basaltic seamounts of the Tasmantid chain, such as Recorder Seamount, were emplaced 25-30 Ma ago in the far northern Tasman. Their volcanogenic aprons form marker horizons in the sedimentary section at abyssal depths in the middle of the basin. The thicker, proximal parts of the aprons are believed to contain a higher proportion of flows and obscure underlying Paleogene sedimentary section in the seismic data.

© Australian Geological Survey Organisation, 1994

INTRODUCTION

The Australian continental margin off southeast Queensland comprises a varying submarine terrain extending down to water depths of about 4800 m. Three major and adjoining sedimentary basins are located in this offshore region: the Maryborough, Capricorn and the northern Tasman Basins (Figure 1). The Maryborough Basin lies both onshore and offshore, while the Capricorn and northern Tasman Basins are located entirely offshore.

Sediments and volcanics in the Maryborough Basin are latest Triassic to Early Cretaceous in age and were deposited in an intra-cratonic setting. The Capricorn and northern Tasman Basins post-date the Maryborough Basin. These younger basins evolved in the Cretaceous during the major episode of plate divergence (Tasman rifting) that resulted in fragmentation of eastern Gondwana and the formation of marginal plateaus, submarine ridges and ocean basins to the east of the present seaboard.

Despite some petroleum exploration activity in this offshore region, particularly during the 1960's and early 1970's, the basins have remained poorly mapped and knowledge of their structure, stratigraphy and evolution has been limited. Not only is this region adjacent to the populous Brisbane area, but it is also located at the southern end of the Great Barrier Reef. Effective management of the offshore resources and environment of this important region is vitally dependent on a sound knowledge of the marine geology.

In 1989 AGSO undertook Project 121.21, a study designed to achieve a better understanding of the geological framework of this region through the acquisition of a new geophysical data set and the follow-up integrated analysis of this and earlier data sets. The new data were collected off southeast Queensland during a 4-week research cruise, AGSO Survey 91 (Enclosure 1), completed in December 1989 using RV *Rig Seismic* (Hill and Pigram, 1990). Multichannel seismic (MCS) and other geophysical data were collected (Figure 2, Enclosures 2 and 3). It was the first MCS survey to be conducted in the region since 1974. This Record reports on the results of the subsequent data analysis and basin study. Current Government policy precludes oil exploration within or adjacent to the Great Barrier Reef Marine Park.

GEOLOGICAL SETTING

REGIONAL PHYSIOGRAPHY

The seafloor off southern Queensland comprises a diversity of submarine landforms, including areas of very high topographic relief (Figure 3). The northern end of the bathymetric Tasman Sea Basin is 200-300 km wide. It is floored by an abyssal plain that lies at about 4000 m depth in the north, and deepens to a depth of about 4800 m to the south (at latitude of Brisbane) - see Enclosure 1. The guyots and seamounts of the south-trending Tasmantid chain rise abruptly above the abyssal plain in the middle of the basin. These edifices are commonly several thousand metres in height. Kenn Plateau forms the eastern margin of the basin. The plateau rises relatively steeply from the basin floor to an undulating upper surface that lies at a mean depth of about 2000 m below sea-level. Cato Island is a

© Australian Geological Survey Organisation, 1994

local topographic high on the western side of the plateau. The island may have a volcanic foundation and form part of the Tasmantid chain (CPCEMR, 1991).

The western (southern Queensland) margin consists of a 20-80 km wide shelf and steep continental slope, which often has a convex profile (Symonds, 1973). The narrowness of the shelf near 25°S is the result of the outbuilding of sand across the old continental shelf to form Fraser Island (Marshall, 1977). The sand dunes on Fraser Island attain a height of 244 m above sea-level. Hervey Bay, on the western side Fraser Island, is a shallow (less than 40 m deep) coastal embayment with sandy bottom. An ancient incised subaerial drainage system extends from the bay to the continental slope. The mainland coastal strip in this region is relatively flat.

The continental slope off southern Queensland has an average slope of 4°- 8°, but can be as steep as 20° in places (Symonds, 1973). 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° 30' S and 25° 50' S and a complex of canyons exists on the slope off Noosa between 26° 10' S and 26° 20' S (Marshall, 1972 and 1978).

The Capricorn Channel (Figure 4), which coincides with the axial region of the Capricorn Basin, 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. Slight increases in seafloor gradient occur between depths of about 120 - 200 m, and depths greater than 600 m (Marshall, 1977). The northeast-striking morpho-structural lineament represented by the southern extremity of the Capricorn Channel and the escarpment just northwest of Cato Island corresponds to the Cato Fracture Zone (Figure 4).

GENERAL BASIN GEOLOGY

A comprehensive account of the regional geology and geological evolution of southeast Queensland is provided by Day et al. (1983).

The Maryborough Basin (Siller, 1961; Ellis, 1966 and 1976; Day et al., 1974) covers an area of about 10,000 km^2 onshore (Figure 4 and Enclosure 4) and at least 15,000 km^2 offshore. Onshore, it occupies the coastal strip from Noosa in the south to about 50 km northwest of Bundaberg in the north. It also underlies parts (or perhaps all) of Fraser Island. The northern and northeastern limit of the basin has conventionally been regarded as the northwest-trending Bunker Ridge (Figure 4), a zone of elevated basement. Correlatives of the Maryborough Basin succession could underlie the younger Capricorn Basin, located to the north and northeast of the Bunker Ridge.

The Maryborough Basin contains a thick sequence of sediments, and some intermediate-acid volcanics, of latest Triassic - Early Cretaceous age overlying basement of Permian - Early Triassic metasediments and granites (Cranfield, 1989; Cranfield, in prep.; Figure 5). The basin possesses one of the thickest Mesozoic sedimentary sections in eastern Australia. The Early Cretaceous Maryborough Formation (shallow marine) and Burrum Coal

© Australian Geological Survey Organisation, 1994

Measures (deltaic) attain a combined thickness of about 5 km. These formations have yielded shows of gas during petroleum exploration drilling (Gray, 1990).

The Capricorn Basin (Figures 1 and 4) underlies the Capricorn Channel. It is about 300 km long and 160 km wide, a little larger in area than the Gippsland Basin. The basin is bounded by the Bunker Ridge to the southwest, the Swain Reefs High to the northeast and the northern Tasman transform margin (Cato Fracture Zone) to the southeast. The northwest limit of the basin is not well defined, but can be considered to be at about 22° S (eg. see Figure 1 in Gulf (1974)). The basin is believed to have evolved in the Late Cretaceous as a failed rift arm at the northern end of the Tasman rift system. The Capricorn Basin contains a sequence of late Mesozoic to Cainozoic non-marine and marine sediments several kilometres thick (Ericson, 1976; Benbow, 1980).

Early Tertiary basins that contain oil shales occur in central eastern Queensland, to the northwest of the study area (Swarbrick, 1974; Day, 1983; Noon, 1984). These basins, which trend north to northwest, could have correlatives well offshore, particularly in the Capricorn Basin. In the coastal area, the basins are deep, narrow grabens or half-grabens, while inland the basins are more extensive in area but thinner. The sediments are argillaceous, deposited in shallow freshwater lacustrine environments. The more important oil shale deposits appear to be of Eocene age; palynoflora studies indicate a Middle to Late Eocene age for the uppermost units in the Narrows Graben (Foster and Harris, 1981).

The continental shelf and slope off the coast between Caloundra and Fraser Island were virtually unexplored prior to Survey 91. The existing seismic data were mainly of poor quality and showed very little deep structure. Profiles across the shelf indicated a prominent, relatively shallow unconformity overlain by a wedge of ?Cainozoic sediments which thickens seaward to at least several hundred metres at the shelf edge. These relatively young sediments are part of the northern Tasman Basin. The AGSO 1970-73 Continental Margin Surveys (CMS) sparker profiles revealed at least limited basin development beneath the unconformity just southeast of Fraser Island.

Fraser Island is a Quaternary landform composed almost entirely of unconsolidated quartz sands. The sands were derived mainly from the rivers of northern New South Wales and were moved northwards by alternating marine and aeolian forces (Grimes, 1982).

Shaw (1990) noted that features typical of passive continental margins such as large-scale taphrogenic basement structure and rift-related sedimentary infill are apparently largely absent across the western margin of the northern Tasman Sea.

The continental rise along the southern Queensland margin of the Tasman Basin is underlain by a narrow depocentre of presumed Late Cretaceous/Cainozoic post-breakup sediments. The depocentre is of significant thickness; 1-2 s twt according to Shell Development (1977). Undulating 'oceanic' basement beneath the abyssal plain in the middle of the northern Tasman is overlain by about 750 m of sediment (Symonds, 1973).

© Australian Geological Survey Organisation, 1994

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

The lithostratigraphic relationships in Maryborough Basin are presented in Figure 5 and discussed in more detail by Cranfield (1989) and Cranfield (in prep.).

The basin consists of two main successions or sub-basins -

(i) latest Triassic to mid Jurassic continental sediments of the Duckinwilla Group (Myrtle Creek Sandstone and Tiaro Coal Measures), and

(ii) latest Jurassic(?) to Neocomian Grahams Creek Formation (containing intermediate-acid volcanics) and two conformable Early Cretaceous units, the Maryborough Formation (Aptian to ?early Albian) and Burrum Coal Measures (Albian).

The Maryborough Formation was deposited mainly in a shallow marine environment; it contains carbonaceous beds and thick sandstone units particularly near its base. The provenance of the formation was from the west and northwest (Cranfield, in prep.). The Burrum Coal Measures were deposited in a delta plain environment with some marine incursions. They contain coal seams that are mined onshore (Enclosure 4). Opinions vary as to transport direction of the Burrum Coal Measures sediments, but it appears likely that the source lay roughly to the east, somewhere between northeast and southeast (Ellis, 1968; Cranfield, in prep.). The sediments were derived from volcanics, perhaps the Grahams Creek Formation or alternatively, equivalents of the Aptian/Albian Whitsunday volcanic belt (Harrington and Korsch, 1985).

The stratigraphy of the Burrum Coal Measures is not well known because of poor outcrop. The formation is about 1700 m thick. Dunstan (1919) subdivided the Burrum Coal Measures into three sections comprising Lower and Upper Unproductive Measures, and a Middle Productive Measures. The more important coal seams are grouped in the Productive member, comprising about 500 m of strata near the middle of the formation (Hawthorne, 1960). Most of the coal production has come from seams within a 150 m section in the middle of the Productive member. The Lower Unproductive member is estimated to have a thicknesss of 1050 m or more.

The Burrum Coal Measures are overlain by a thin fluviatile sequence of mid Tertiary age, the Elliott Formation.

Inter-well correlations (see Enclosure 4 for well locations) and the latest stratigraphic sub-division of the Maryborough Formation (Derrington, 1981) are presented in Figure 6. The basal unit of the Maryborough Formation is the Gregory Sandstone Member. It is about 500 m thick. Conglomerates near the base of this sandy member are believed to be responsible for a strong seismic marker horizon that can be traced over much of the basin.

A basin-wide stratigraphy for the Capricorn Basin had not been developed prior to this study mainly because of the very limited lithostratigraphic control available. Capricorn 1A (Carlsen and Wilson, 1968a) and Aquarius 1 (Carlsen and Wilson, 1968b) are the only deep wells drilled in the basin; both are located in the northern part of the basin (Figure 4). Figure 7 shows lithostratigraphic logs of these wells based on a revised biostratigraphic interpretation by Chaproniere et al. (1990). Continental rift-phase conglomerates and red-beds of Late Cretaceous-Paleocene age overlie basement. These are unconformably overlain

© Australian Geological Survey Organisation, 1994

by Eocene mixed marine/continental quartzose sandstones and lignites, which are in turn unconformably overlain by a thick marine sequence of Late Oligocene - Recent limestones and marl. The quartz sand and lignite facies contains beds of anhydrite suggesting both deltaic and sabkha-type environments.

Capricorn 1A and Aquarius 1, to which the Survey 91 lines were tied, provide the main stratigraphic control in the Capricorn / northern Tasman Basin region . The Wreck Island bore (TD 578 m; Humber, 1960) to the southwest and GSQ Sandy Cape 1-3R stratigraphic drill-hole (TD 623 m; Grimes, 1982) at the northern tip of Fraser Island provide additional control; both intersected a late Cainozoic shelfal section.

Very little is known of the the stratigraphy of the the deep-water northern Tasman Basin. The relatively thick (> 1 km) section adjacent to the Australian margin has not been drilled, nor has the middle of the basin in this area. The nearest Deep Sea Drilling Project sites are 208 (Leg 21; Burns, Andrews et al., 1973) and 588 (Leg 90; Kennett, von der Borch et al., 1985), which are located close together on the western side of the northern Lord Howe Rise, 600 km ESE of the study area. The deeper hole at Site 208 terminated in a middle Paleocene to Cretaceous sequence at 594 m sub-bottom. At this site, Late Cretaceous to early Middle Eocene siliceous fossil-bearing chalk underlies Late Oligocene to late Pleistocene calcareous ooze.

The age progression in the 'hotspot' Tasmantid seamount chain, which includes Recorder, Moreton and Brisbane Seamounts, has been established by radiometric dating (McDougall and Duncan, 1988). Knowing the age of a particular seamount allows approximate dating of volcaniclastic / lava bearing horizons adjacent to the seamount. Such volcanic 'marker' horizons provide useful stratigraphic control in the northern Tasman Basin. *Rig Seismic* survey lines are as close as 12 km to the base of Recorder Seamount (Enclosure 2). This large submarine volcano has an estimated age of 25±2 Ma.

Chaproniere et al. (1990) recognised three regional unconformities throughout offshore northeast Australia. These unconformities are present in the middle Eocene, early Oligocene and middle-late Miocene.

- The mid Eocene unconformity was interpreted to be the result of vertical movements produced by intraplate stress.
- The cause of the early Oligocene unconformity was difficult to establish (Chaproniere et al., 1990). It was concluded that the hiatus appeared to to be related to major changes in ocean current circulation associated with northward drift of Australia, and perhaps the flow of corrosive bottom waters into the region. The unconformity can also be correlated to a major eustatic sea-level lowstand at 30 Ma (Haq et al., 1988).
- The middle-late Miocene unconformity was attributed to sea-level fall by Chaproniere et al. (1990). The unconformity presumeably corresponds to the major eustatic lowstand at 10.5 Ma (Haq et al., 1988).

STRUCTURE

The Maryborough Basin trends NNW, parallel to the regional structural grain of the New England Fold Belt. Deformation in the mid-Late Cretaceous resulted in faulting and folding, and produced the major synclinorium in the Early Cretaceous (and ?older) units that is the

© Australian Geological Survey Organisation, 1994

major structural feature of the basin (Enclosure 6). The basin has been described as a pseudo-graben (Petroleum Resources Assessment and Development Subprogram, 1990).

A series of broad, open folds with northwest trending axes occur 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). Offshore in the Hervey Bay area, seismic data indicate a large, faulted syncline in Early Cretaceous sediments (Tiger, 1969; Baxmann, 1971). The Early Cretaceous section is truncated by a strong erosional unconformity, and blanketed by a flat-lying Cainozoic sediment cover that gradually thickens seaward to about 500 m at the shelf edge.

Faults are high-angle, both normal and reverse. Some of the more definitive information on faulting in the basin comes from the collieries. In the Burrum Coalfield, faults fall into two clearly defined groups with almost orthogonal strike directions (Hawthorne, 1960). Faults of one group are reverse faults which trend 320-335°, almost parallel to the fold axes. Faults of the other group trend 25-50°; at least some of these are normal faults - there is no regular pattern in displacement direction. Observed throws are typically only a metre or so, though some of the larger faults have throws of 10-20 m.

Ellis (1966) suggested that the fold structures are drape folds produced by strong repetitive normal faulting of basement with downthrow to the east. In contrast, others such as Elliott (1993) favour compressional tectonics as the cause.

The axis of the Capricorn Basin trends northwest. Faulting and an irregular basement surface indicate a complex history at depth (Ericson, 1976). Normal tensional faulting, with general northwest strike, near the basin axis appears to have initiated subsidence by late Mesozoic. The upper part of the section (middle Tertiary and younger) shows little structural deformation.

TECTONICS

The Mesozoic-Cainozoic tectonic development of the region (New England Orogen) is discussed and interpreted by Jones and Veevers (1983) and Harrington and Korsch (1985).

Chilean-type subduction (arc on the continental margin), which had prevailed on the eastern Australian margin since the Devonian and had resulted in its formation by associated volcanism and terrane accretion, changed to Mariana-type subduction (arc separated from the continent by back-arc spreading) in the Cenomanian (Veevers, 1990). During the Cenomanian transition phase, the eastern Australian plate boundary may have resembled the present plate boundary along western North America (Jones and Veevers, 1983), with a volcanic arc along the Queensland coast north of Brisbane and a sinistral obique-slip zone along the incipient Tasman Sea rift off what is now southeast Australia.

In the Permian and Mesozoic, eastern Australia was in a back-arc tectonic setting dominated by a strike-slip regime (Korsch et al., 1989). Basins developed as oblique extension stepped eastwards. Localised displacements in the Surat and Clarence-Moreton Basins indicate that strike-slip movement continued into the Cretaceous (Korsch et al.,

© Australian Geological Survey Organisation, 1994

1990; O'Brien et al., in press). Basin development was seen basically as a two stage process - transtensional rifting, followed by thermal relaxation subsidence.

The Maryborough, Surat, Clarence-Moreton and Nambour Basins were probably once joined (Day et al., 1974), having developed as a large Jurassic-Cretaceous foreland basin behind a magmatic arc located to the east (Elliott, 1993). Doutch and Nicholas (1978) also suggested that the Maryborough Basin may have evolved as a foredeep.

Since late Mesozoic time the geological evolution of eastern Australia has been dominated by the continental rifting and seafloor spreading tectonic episodes which led to the formation of the Tasman Basin and Cato Trough (Veevers, 1991). The magnetic anomaly pattern in the Tasman Sea indicates that seafloor spreading was active between chrons 33-24, about 80-55 Ma (Hayes and Ringis, 1973; Weissel and Hayes, 1977; Shaw, 1978, 1979 and 1990). Spreading was oblique and propagated northwards. The extreme northern part of the Tasman Basin opened between magnetic anomalies 27-24, i.e. 63-55 Ma or Late Paleocene - Early Eocene (Figure 4). Seafloor spreading failed to propagate into the Capricorn Basin, and was instead diverted farther northeast to the Cato Trough via the Cato Fracture Zone.

In the reconstruction of Weissel and Hayes (1977), extensive early opening is implied suggesting that Kenn Plateau may be oceanic or that it experienced a considerable degree of crustal extension. Shaw (1978), on the other hand, adopts more southerly finite poles and infers that prior to chron 30 the 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 southeast edge of the proto-plateau. According to Shaw's (1978) model, several hundred kilometres of sinistral movement between Australia and the Lord Howe Rise took place during opening of the Tasman.

Models advanced for the development of Australian continental margins (Falvey, 1974; Falvey and 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-Paleocene 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 (Lister et al., 1986; Lister and Etheridge, 1989; Lister et al., 1991) may be applicable to the conjugate southern Queensland / Kenn Plateau margins, at least on the basis of asymmetric margin morphology. In such models the eastern Australian margin is considered to be an underplated upper plate.

A major change in global plate kinematics occurred in the mid Eocene. Intraplate stresses generated by this plate reorganisation are believed to have produced deformation in basins along the eastern and southern margin of Australia (Etheridge et al., 1991). The main structural petroleum traps (anticlines) in the Gippsland Basin were created at this time (Esso, 1988). Change in motion of the Pacific plate at 43 Ma (Dalrymple et al., 1980) is manifested by the bend in the Emperor-Hawaii chain. Coincident was the onset of rapid separation of Australia and Antarctica (Veevers et al., 1991). Ophiolite obduction and metamorphism at the edge of the Australian plate - in Papua, North Solomons and New

© Australian Geological Survey Organisation, 1994

Caledonia (Kroenke, 1984; Paris, 1981) - are less distant examples of roughly contemporaneous tectonism. The plate boundary along the northern Norfolk Ridge became obliquely convergent at this time (Walley, 1992).

The southeast Queensland oil shale basins such as Rundle and Condor (Day, 1983) are believed to have been generated by Eocene transtensional motion in eastern Australia (Veevers, 1990), perhaps related to the global plate reorganisation mentioned above. These basins are typically about 10 km long, mostly less than 10 km wide and about 1 km deep. Gravity anomalies over these structures show a distinctive bi-lobate or compartmented pattern that may reflect depositional lobes or cross-warping in the basins (McIver et al., 1992). The structural characteristics of the basins suggest development as wrench or pull-apart basins. The evidence therefore points to the existance of a transtensional stress field in this continental region during the ?mid Eocene.

GEOPHYSICAL AND GEOLOGICAL SURVEYS / DRILLING

PRESENT EXPLORATION STATUS

An onshore part of the Maryborough Basin is currently held under exploration licence (permit 504P). There are no offshore leases, nor are there any plans by Government to make offshore acreage available within, or in proximity to, the Great Barrier Reef Marine Park, which extends southward to 24° 30' S and includes the northern extremity of the Maryborough Basin (Figure 2). This is in accordance with Great Barrier Reef Park Act 1975 and the present moratorium on petroleum exploration activity in areas immediately adjacent to the Marine Park announced by the Australian Government in July 1990. All but the deep-water southeastern part of the Capricorn Basin lies within the boundaries of the Marine Park (Figure 2).

PREVIOUS SEISMIC PROFILING AND EXPLORATION DRILLING

The Maryborough Basin has had a long history of petroleum exploration, dating back to at least 1923 when the first shallow wells were drilled. Activity has waxed and waned since then, but overall the basin has remained lightly explored. Exploration in the Capricorn Basin peaked in the late 1960's, with the exploration effort being concentated in the shallower, northern part of the basin. Most of this basin has little more than reconnaissance-level seismic coverage.

In the Maryborough Basin only four deep wells (Table 1) have been drilled onshore, and none offshore. Drilling to date has been aimed mainly at the lower sandy beds of the Early Cretaceous Maryborough Formation in major anticlinal structures.

Gregory River 1, drilled in 1966/67, flowed gas (mainly methane) at 5660 m^3/day from the 'lower sandy member' (i.e. Gregory Sandstone Member) of the Maryborough Formation (Shell Development (Aust.) Pty Ltd, 1967). In 1981 Gregory River 2 (Derrington, 1981) was drilled 3.6 km to the NNW on the same anticlinal structure. Though gas shows were recorded from the Burrum Coal Measures and a number of intervals in the Maryborough Formation, there were no major gas flows because of poor porosity and permeability.

© Australian Geological Survey Organisation, 1994

Early seismic reflection surveys of the onshore Maryborough Basin include, (i) a 1958 survey by Foreign Oil Exploration for Lucky Strike Drilling Co. in the Pialba - Susan River - Cherwell area, and (ii) a 177 km survey in 1961 by Austral Geo Prospectors for Pacific American Oil Co. of the Susan Anticline. Data were recorded to only 1.8 s during the latter survey. These surveys revealed that the Susan River well had been drilled on the north plunge of a faulted anticline, and that it was 215 m lower than a culmination located 3 km to the southeast of the well site (Derrington, 1981). The most extensive and best quality onshore reflection and refraction seismic was shot by Shell in 1963 (Bruce and Thomas, 1964). In 1967-68 a weight drop / explosives seismic survey in the onshore Bundaberg area by Namco Geophysical Co. (1968) produced data that were mostly of poor quality.

Marine seismic data shot pre-1969 by Shell Development in the Hervey Bay area (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 streamer and airgun array to record 24-fold data.

Enclosure 3 shows the seismic coverage of the principal and most useful surveys conducted over the main part of the Maryborough Basin.

Wreck Island 1 (Enclosure 2; Humber, 1960) was the first exploratory bore drilled in the Capricorn Basin area. The bore, located on the northern Bunker Ridge, reached a total depth of 579 m. The last 31 m penetrated siliceous volcanic conglomerates considered to be Grahams Creek Formation. The overlying succession comprised early Miocene to Recent marine sediments; no late Miocene was encountered.

In the northern Capricorn Basin, an extensive grid of sparker/dynamite seismic lines was shot by Australian Gulf Oil during 1965-66 (Australian Gulf Oil Co., 1966 and 1967; Wilson, 1967), prior to the drilling in 1967 and 1968 of exploration wells Capricorn 1A and Aquarius 1 (Figure 4; Table 1; Carlsen and Wilson, 1968a & b). Both holes were dry. Capricorn 1A reached a total depth of 1710 m in Cretaceous volcanics, while Aquarius 1 (drilled 40 km to the northeast) penetrated 'basement' of ?Paleozoic, slightly metamorphosed shales and sandstones at 2643 m and was abandoned at a total depth of 2650 m. Apart from one line shot during a United Geophysical survey in 1970, the only multichannel industry surveys undertaken in the Capricorn Basin since then have been reconnaissance surveys conducted during 1973-74 by Gulf (1974) and Shell Development (1977).

Surveys 12, 13, 14 and 15 of the AGSO 1970-73 Continental Margin Survey (CMS) program provide broad regional seismic coverage over the northern Tasman Basin, the southeast Queensland continental shelf and the Capricorn Basin (Enclosure 2; Symonds, 1973; Mutter, 1974). No data were collected in Hervey Bay. The seismic data quality was poor-fair in shallow-water areas such as on the shelf, with penetration limited by the relatively low power of the sparker source.

A single-channel airgun seismic survey in 1980 by RV *Sonne* collected 711 km of shallow data on the inner-middle shelf off central Fraser Island (Nunn, 1982). The survey was aimed at investigating mineral sand deposits. Seismic data quality was very poor to fair.

© Australian Geological Survey Organisation, 1994

GRAVITY AND MAGNETIC SURVEYS

Early gravity work in the area included a northeast-southwest gravity traverse across Hervey Bay in 1958-59 (Dooley, 1959). Shell made gravity observations on Fraser Island and the mainland adjacent to Hervey Bay in 1973 (Smith, 1965). These data are supplemented by the AGSO regional network of land stations, which are spaced about 10 km apart.

Shipboard gravity and magnetic data were collected during AGSO Surveys 12, 13, 14 and 15 of the CMS program (Enclosure 2). This data set provides the most extensive regional ship-acquired geopotential coverage of the offshore region. Gravity data were also collected in the study area during AGSO Surveys 50, 75 and 76 while *Rig Seismic* was in transit to survey areas farther north.

Gravity and magnetic data were acquired during the 1973 M/S *Gulfrex* reconnaissance geophysical survey in the Capricorn Basin and southern Great Barrier Reef (Gulf, 1974).

The 1964 Swain Reefs aeromagnetic survey by Australian Gulf Oil (Affleck and Landau, 1965) covered the offshore area to the north of Fraser Island (see Figure 17 in Hill and Pigram (1990)), and superseded previous aeromagnetic work over this region. Low-altitude aeromagnetic surveys flown by AGSO in 1986-87 have extended detailed coverage over the Maryborough Basin to the south of the Gulf Oil data (see Figure 16 in Hill and Pigram (1990)). The AGSO flight lines cover only the near-shore part of the continental shelf (10-30 km off the coast).

ONSHORE STRATIGRAPHIC DRILLING

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 623 m-deep stratigraphic hole (GSQ Sandy Cape 1-3R, Figure 2) was drilled on the northern tip of Fraser Island (Grimes, 1982; Palmieri, 1984; Wood, 1986). 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.

Many of the shallow stratigraphic holes drilled in the Moon Point and Wide Bay coastal areas penetrated the extensive late Cainozoic sediment sheets present here and sampled underlying bedrock (Queensland Department of Mines, 1981; Grimes, 1992; Enclosure 4). The southeastern onshore Maryborough Basin appears to be more structurally complex than elsewhere; mapping of the basin here is further complicated by paucity of outcrop. Consequently, the drilling information is an important control and aid in mapping the basin in this area.

© Australian Geological Survey Organisation, 1994

In the Wide Bay area, drilling showed that Maryborough Basin bedrock (Maryborough Formation and Duckinwilla Group) lies 30-50 m beneath overlying Quaternary sandy coastal deposits. Measured dips in the most commonly encountered bedrock unit, the Duckinwilla Group, were in the range 8-40° (Grimes, 1992). All bedrock cores were barren of pollen, possibly due to over-maturation.

MARINE GEOLOGICAL SAMPLING

Geological surveys of the continental shelf and upper continental slope off southern Queensland were carried out by AGSO in 1970 and 1972 (Marshall, 1977 and 1980), and also during *Sonne* cruise SO-15 in 1980 (Stackelberg, 1982).

Lithified samples were dredged from two locations on the upper continental slope off the northern end of Fraser Island. 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. Sediments on the shelf east and southeast of Fraser Island are considered to be relict and are composed predominantly of sands. The sands are quartz-rich inshore and carbonate-rich towards the shelf edge. The carbonate component at the shelf edge is 60% or more; the skeletal fragments are mainly of foraminifera, molluscs, echinoderms and calcareous red algae.

VERTICAL TECTONICS AND THERMAL HISTORY

Reliable temperature data for estimating geothermal gradient and heat flow are available from only one well in the Maryborough Basin, Gregory River 2. The stabilised geotemperature at total depth was estimated as 244°F (117.8°C) - H. Crocker in Derrington (1981). This gives value of 29.5°C/km for the geothermal gradient. Assuming a thermal conductivity of 2.2 W/m-K (rough value based on lithologies and various references on sediment thermal conductivity), the present-day heatflow is calculated to be 65 mW/m^2. Such a value is typical of continental Australia (Cull and Conley, 1983).

Vitrinite reflectance data from the onshore wells in the Maryborough Basin show fairly high values, mainly in the range 1.0 to 4 (Keiravile Konsultants Pty Ltd (1984), Table III.5 in Petroleum Resources Assessment and Development Subprogram, 1990). Values are believed to be high because of depth of burial and high heat flow that preceded and accompanied opening of the adjacent Tasman Sea in the Paleocene.

High values of vitrinite reflectance and thermal alteration index (TAI) in outcrop and near-surface samples indicate that a considerable part of the basin section has been removed by erosion.

Geohistory analyses of Capricorn Basin drill-hole data (Chaproniere et al., 1990) constrain the subsidence history of those parts of the basin where these data are available. Such data are only available for the northern and western areas of the basin - from the Capricorn 1A, Aquarius 1, Wreck Island and Sandy Cape 1-3R drill-sites. Biostratigraphic control is good for the Neogene, but less reliable for the Paleogene sections penetrated in Capricorn 1A and Aquarius 1. Tectonic subsidence plots (Chaproniere et al., 1990) show general consistency

© Australian Geological Survey Organisation, 1994

among the wells suggesting that the northern and western parts of the Capricorn Basin underwent similar gradual tectonic subsidence of about 11-16 m/Ma through the Eocene to Miocene, followed by onset of rapid subsidence (about 80 m/Ma) in the Pliocene. This rapid late Cainozoic subsidence is interpreted as a regional effect, possibly produced by intraplate stress (Lambeck, 1983; Chaproniere et al., 1990).

Following breakup, a simple continental margin would be expected to cool and subside exponentially with time. Vertical movement of the continental margin in the southern Queensland region during the early-mid Tertiary may have been modified by several tectonic processes:- (i) underplating of the upper plate margin during detachment faulting (Lister and Etheridge, 1989) - resulting in uplift, (ii) mid Eocene intraplate stress that produced uplift and structural reactivation (discussed in a later section), and (iii) transit of this part of the Australian plate over a mantle plume [the eastern part of the region passed over the Tasmantid Seamount 'hotspot' between about 35-20 Ma (McDougall and Duncan, 1988). A similar mantle plume may have been active further west beneath continental crust of the coastal region (Johnson et al., 1989)].

While there has been overall margin subsidence during the post-breakup period, there has also been uplift of the Eastern Highlands and associated volcanism (Shaw, 1990). Jones and Veevers (1983) place initiation of uplift at 90 Ma. In a review of causal mechanisms and timing for the uplift, Wellman (1987) favoured the interpretation that uplift occurred mostly during the Cainozoic and that it was associated with episodic volcanism and underplating.

No fission track data are presently available for the immediate Maryborough/Capricorn Basin area (A.J.W. Gleadow, pers. comm.). Information is available, however, for the Clarence-Moreton Basin to the south (Gleadow, 1989; Gleadow and O'Brien, in press). Analysis of apatite fission track data from both outcrop and well samples within the basin and underlying basement granites, indicate:-

- a clearly defined trend from older (~160 Ma) fission track ages at the inland northeastern edge of the basin to younger (50-60 Ma) reset ages at its eastern margin. This resetting is attributed to heating and uplift associated with opening of the Tasman Sea. A similar regional pattern of decreasing apatite age towards the continental margin was found by Moore et al. (1986) in basement rocks from southeast Australia. Here the youngest apparent ages were 80-100 Ma, reflecting earlier opening of the Tasman in the south.
- a considerable thickness, 2-3 km, of sediment was removed by erosion.

An analogous thermal event and uplift would be expected for the far northern sector of the Tasman Sea margin (in the vicinity of Fraser Island), including the Maryborough Basin. Here the thermal pulse and uplift probably post-dated similar events in the Clarence-Moreton Basin by several million years because of the delayed opening of the extreme northern Tasman (Shaw, 1990). Maximum heating in the Maryborough Basin is inferred to post-date folding and emplacement of other major structure in the mid Cretaceous.

© Australian Geological Survey Organisation, 1994

AGSO SURVEY 91 DATA

The extent of the new geophysical coverage over the offshore Maryborough Basin and adjacent areas is indicated in Figure 2 and Enclosures 1 and 2. The survey included seismic ties to Aquarius 1 and Capricorn 1A wells in the northern Capricorn Basin. These well sites are located within the boundaries of the Great Barrier Reef Marine Park (GBRMP), but were drilled before the GBRMP was gazetted. As they are the only deep offshore wells in the region, tying to them was vital for stratigraphic control of the seismic data in the basins to the south. The GBR Marine Park Authority issued a research permit (G89/497) to enable this work to be conducted.

The offshore Maryborough Basin was investigated by two survey line networks, one grid in Hervey Bay and the other on the continental shelf southeast of Fraser Island. Survey 91 was the first MCS survey shot in the Hervey Bay area since 1970, and the first such survey to be shot in the region since 1974.

Acquisition details are provided in the post-cruise operational report (Hill and Pigram, 1990).

During this survey a total of 2900 km of MCS data was acquired along 31 lines (Figure 2 and Enclosure 2). The 24-fold data were recorded at a ships speed of 5 knots using a 2400-m 96-channel streamer and dual tuned airgun array source (52 litre capacity). Record length was 12 s to allow definition of deep structure. In addition, a total of 10 sonobuoy refraction and wide-angle reflection experiments were completed along selected parts of the seismic lines to assist interpretation of crustal structure. Sonobuoys were successfully deployed on the continental shelf southeast of Fraser Island, in Hervey Bay, over the northern Tasman Basin and over the central Capricorn Basin (Figure 2).

Gravity and bathymetric data were collected along all lines (i.e. both seismic and transit; see Enclosure 1) 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. Adequate coverage in these areas is provided by detailed 1986-7 AGSO aeromagnetic surveys. Magnetic data were also acquired on the long transit made through the survey area at the conclusion of the seismic program (see Figure 29 in Hill and Pigram (1990)). A total of 2450 line-km of magnetic profile data were acquired during the cruise.

All survey data - navigational, bathymetry, geopotential and MCS - have been processed at AGSO. The complete set of field and processed data was made publically available as AGSO Data Release 31 in July 1992.

REGIONAL BATHYMETRY, GRAVITY AND MAGNETIC COMPILATIONS

New regional bathymetry and geopotential maps have been produced for the study area. They are all at 1:500 000 scale and comprise: (i) bathymetric contours, at 200 m contour interval plus the 100 m contour (Enclosure 2), (ii) free-air gravity anomaly contours

© Australian Geological Survey Organisation, 1994

offshore and Bouguer anomaly contours onshore, at 5 mGal contour interval (Enclosure 4), and (iii) marine magnetic anomaly profiles, at 100 nT/cm scale (Enclosure 5).

The data sources on which these compilations are based are listed below.

Bathymetry

1. AGSO Survey 91.
2. AGSO Continental Margin Surveys (CMS) 12, 13, 14 and 15 of 1970-73.
3. National Bathymetric Map Series, 1:250 000 scale (Division of National Mapping / Hydrographic Service, Royal Australian Navy) - sheets: Bundaberg, Maryborough, Sandy Cape, Wide Bay, Caloundra, Brisbane.
4. (i) Chart Aus 367 (North Reef to Pine Peak Island), 1:300 000, British Admiralty / Hydrographic Service, Royal Australian Navy,
   (ii) Chart Aus 4602 / INT 602 (Tasman and Coral Seas), 1:3 500 000 - Hydrographic Service, Royal Australian Navy,
   (iii) Chart 1024 (Fraser Island to Cumberland Islands), 1:1 000 000, British Admiralty / Hydrographic Service, Royal Australian Navy.
5. "Bathymetry of the South Pacific", Sheet 11, 1974 - J. Mammerickx, T.E. Chase, S.M. Smith and I.L. Taylor - Scripps Institution of Oceanography.
6. 1973-74 Offshore Queensland Seismic Scientific Investigation (Shell Development, 1977).
7. 1990 PACRIM-WEST seafloor swath-mapping survey by Seafloor Surveys International using System09 (Sydney-Guam cable route survey for OTC (Australia)).

Gravity

1. AGSO Survey 91
2. AGSO 1970-73 CMS 12, 13, 14 and 15
3. Shell Development survey on Fraser Island and adjacent mainland (Smith, 1965 - Enclosure 3 in SDA Report 57)
4. AGSO (*Rig Seismic*) Surveys 50, 75 and 76
5. Geophysical reconnaissance survey by M/S *Gulfrex* in 1973 (Gulf, 1974)
6. "Bouguer anomalies", Brisbane, Sheet G56 - AGSO map 21-1/G56, 1:1 000 000, 1983.

Magnetics

1. AGSO Survey 91.
2. AGSO 1970-73 CMS 12, 13, 14 and 15.

BATHYMETRIC FEATURES

Most of the gross features seen in the new bathymetry compilation (Enclosure 2) have been described in an earlier section (Regional Physiography). The following are additional comments based on the new compilation and the Survey 91 results, in particular.

The southern Queensland continental shelf is mostly less than 100 m deep; the shelf break is at about 300 m depth. The continental slope in this area is steep, with a mean gradient of

© Australian Geological Survey Organisation, 1994

about 1:8 (~7° slope), and also narrow (~ 35 km wide). The slope is cut by a number of canyon systems, some of which cross the slope obliquely. The canyons are typically several hundred metres deep. Canyon development at the margin is believed to be controlled by rift structures in bedrock and post-breakup slump masses. Canyon systems are located on the continental slope at latitudes 24° 53', 25° 09', 25° 32', 25° 47', 26° 01', 26° 21', and 26° 46'.

A large submarine valley is present at the junction of the southern Queensland rift margin and the northern Tasman transform margin. This valley forms the most southern and deepest part of the Capricorn Channel. Water depths within the valley range from several hundred metres to about 3500 m. Its floor has been eroded and incised by channels and canyons. The erosional features form a large dendritic 'drainage' pattern (see Enclosure 20), the branches of which converge on a master canyon that opens out onto the abyssal plain of the northern Tasman Sea Basin.

A number of local seafloor topographic highs, with up to several hundred metres relief, have been mapped in and around this valley. These may be erosional remnants or structural highs. It is quite likely, however, that they are Tertiary volcanic buildups. Two such volcanic edifices were imaged at the western end of line 091/30 (see Enclosure 34).

The northern Tasman transform margin has a relatively gentle upper slope. It drops southward towards the Tasman at about 2°. The lower part of the slope (below ~2000 m depth) steepens to about 5°, not quite as steep as the continental slope east and southeast of Fraser Island. Sediment slumps have changed the morphology of the lower slope (see Enclosure 34), producing hummocky seafloor topography with up to 150 m relief.

QUALITATIVE INTERPRETATION OF GEOPOTENTIAL DATA

GRAVITY

The gravity field over the region (Enclosure 5) shows considerable variation, mainly ranging from -80 to +70 mGal, though even higher values of free-air anomaly in excess of +150 mGal occur locally over the summits of large seamounts such as Recorder Seamount. The gravity anomalies in the offshore area primarily reflect changes in water depth, crustal structure and sediment thickness.

The contours display pronounced northwest and NNE trends, plus trends orthogonal to these two directions. These trends are an indication of the main underlying structural grain. A strong continental shelf edge anomaly, consisting of a prominent inboard gravity high and associated outboard gravity low, is seen in the data over the continental slope east of Fraser Island, adjacent to the Cato Fracture Zone and adjacent to the Cato Trough. The anomaly is due to the interacting gravitational effects of crustal thinning and increase in water depth basinward across the margin.

The gravity expression of the Maryborough Basin is relatively subdued (about 10 mGal), considering the basin is known to contain at least several kilometres of Early Cretaceous section alone. It implies a mean density contrast between basement and basin fill of less than 0.1 t/m^3. This, together with recorded relatively high seismic velocities in the order of 4000 m/s, suggests low porosity, i.e. tight/indurated formations. Relatively high sediment density,

© Australian Geological Survey Organisation, 1994

resulting from induration plus the presence of volcanics, probably accounts for much of the subdued expression. A contributing factor may be relatively low density of the basement rocks. If this is the case, it suggests that granites may form much of basement.

Gravity lows are associated with areas of the Maryborough Basin known to have thick section. These areas include the western side of Hervey Bay and adjacent onshore region. A low located over the southern part of Fraser Island also probably indicates thick section. Gravity lows in the western past of the map area are due to mid Triassic and older granite bodies.

In the gravity contours, the Capricorn Basin is seen as a northwest-trending low to the south of the Marion Plateau. The prominent line of highs down the middle of the Tasman are basaltic seamounts of the Tasmantid chain, a mantle hotspot trace. These volcanoes were erupted over a hotspot (now located in the southern Tasman at latitude ~40° S), as the Australian plate drifted northward during the Cainozoic.

Apart from the most southern part of the basin, seafloor topography in the Capricorn Basin mostly varies smoothly throughout the basin, i.e. there is no major local seafloor relief. As a result, gravity anomalies would be expected to reflect changes in depth to basement (sediment thickness). The areas of relatively low free-air anomaly, arbitrarily defined by the +10 mGal contour (Enclosure 5), are potentially areas of thick sediment. A major northwest-trending gravity low (of less than -10 mGal) is located in the central western part of the basin and is believed to coincide with the main axis of the basin. Other gravity lows, particularly those to the north and east, probably define local depocentres. The gravity expression of the basin indicates some complexity in basement architecture, suggesting that the Capricorn Basin developed by more than a simple rifting.

Figure 8, based on gravity modelling, depicts and compares interpreted crustal structure across the northern Tasman and southern Capricorn Basin. An onshore crustal thickness of 36 km is assumed, based on deep seismic transects to the southwest (Finlayson et al., 1990). The results indicate a uniformly thin crust, presumed oceanic, about 10 km thick beneath the Tasman. Similar crust is interpreted beneath Cato Trough. The crust beneath the Capricorn Basin has thinned very little, only about 7 km, suggesting that the amount of extension by rifting has been small.

MAGNETICS

The AGSO 1986-87 aeromagnetic data outline the Maryborough Basin quite well and reveal subsurface structure - see Figure 16 in Hill and Pigram (1990). Volcanics within the Grahams Creek Formation and associated igneous intrusions have strong magnetic expression. [Magnetic susceptibility measurements by the author and L. Cranfield (GSQ) on outcrops of Grahams Creek Formation in the central Maryborough Basin gave values ranging from almost zero (rhyolites) to very high (andesitic flows and pyroclastics, typically 200-3000 x 10^{-5} SI)]. The general smooth, long-wavelength nature of the field over the basin continues to the southeast over the inner continental shelf southeast of Fraser Island. This suggests that basin development extends into this area, where the basin had not been mapped previously. The limited offshore coverage of the aeromagnetics does not allow the basin to be traced very far onto the shelf.

© Australian Geological Survey Organisation, 1994

The AGSO marine magnetic profiles (Enclosure 6) provide data farther offshore. The magnetic profiles are fairly smooth to the southeast of the southern tip of Fraser Island, suggesting that the basin might in fact extend right across the shelf. Large anomalies in an area between Wide Bay and Noosa are likely to be due to relatively shallow Late Jurassic - Early Cretaceous subvolcanics.

A magnetically anomalous field covers northern Fraser Island, the adjacent continental shelf, and the shelf off central Fraser Island. The anomalies in this region are mainly of low-moderate amplitude and short wavelength, suggesting relatively shallow source depth. The anomalies are partly, perhaps totally, produced by Cainozoic basalts - as exposed at Waddy Point and intersected in Sandy Cape 1-3R. The area may also be underlain at shallow depth by volcanics of the Grahams Creek Formation.

Seismic mapping shows that the Grahams Creek Formation subcrops along a NNW trend beneath mid-late Cainozoic cover in the middle of Hervey Bay (see later sections and Enclosure 4). The AGSO aeromagnetic data cover only part of this zone. However, where coverage is available no significantly anomalous expression of the subcrop is evident in the magnetics. This may be explained in part by the greater sensor-source distance compared to data flown over Grahams Creek Formation outcrop onshore (offshore the Maryborough Basin strata are covered by several hundred metres of Cainozoic deposits). The main reason for the minor magnetic expression may be that the unit thins appreciably to the northeast beneath Hervey Bay and/or that the unit here comprises mainly volcaniclastics and few, if any, flows or high-level intrusions

East of the southern Queensland shelf edge, the anomalies are smooth and of long wavelength because of the great water depth in the Tasman Sea. Magnetic variations over the deep-water areas of the Tasman include the seafloor spreading magnetic lineations (Figure 4) and the often large (> 1000 nT) anomalies associated with the basaltic volcanoes of the Tasmantid seamount chain. The magnetic lineation pattern is not well defined because of the field distortions produced by the seamounts, and also because the northern Tasman Basin is relatively narrow and the spreading segments appear to be relatively short.

The magnetic field over the far northern end of the Tasman is almost featureless. No pronounced anomaly is associated with the inferred Cato Fracture Zone, though some change in character of the field is observed in crossing from the Tasman to the Capricorn Basin. As expected, the profiles exhibit an increase in short wavelength content correlative with decrease in water depth across the transform margin.

The magnetic anomaly field over the Capricorn Basin is of low to high (several hundred nT) amplitude and generally of moderate wavelength. These characteristics of the field are consistent with magnetic basement depths in the order of one to several kilometres and a basement that possesses significant magnetisation contrast (resulting from structured magnetic basement and/or infra-basement magnetic heterogeneity). Basement could, in part at least, comprise volcanics and subvolcanics of an erosionally truncated andesitic magmatic arc or volcanic rift (?Whitsunday Volcanics / Grahams Creek Formation, as intersected in Capricorn 1A and Wreck Island 1) - see Figure 27A in Elliott (1993). The field is fairly flat over some parts of the axial region of the basin, suggesting deep magnetic basement in these local areas. Though many of the major basement faults seen in the seismic have expression

© Australian Geological Survey Organisation, 1994

in the magnetics, the available data show no obvious major basin-wide trends or patterns that might convey significant additional information on the large-scale structural framework of the Capricorn Basin.

SEISMIC STRATIGRAPHY

MARYBOROUGH BASIN

Three main seismic horizons were recognised in the reflection data of the 1963 onshore survey by Shell Development (Bruce and Thomas, 1964):-

1. a top Maryborough Formation horizon,
2. a Grahams Creek Formation horizon, and
3. a deep horizon believed to be associated with Paleozoic sediments.

The quality of seismic data shot in the offshore Hervey Bay area improved dramatically in 1969 and 1970 when Shell Development started using airgun MCS (Tiger, 1969; Baxmann, 1971). These surveys revealed three seismic marker horizons - A, A1 and B - that could be correlated and mapped over the survey area with a fair degree of confidence. Correlation of these horizons with stratigraphic levels in the onshore wells was hindered by the lack of a direct tie between onshore and offshore seismic networks (due to difficulties in surveying the very shallow nearshore area of western Hervey Bay). Nevertheless, a tentative correlation was made. This was as follows:-

A: top of Maryborough Formation,
A1: top of Upper Sandy Member of the Maryborough Formation
B: marker in the Lower Sandy Member of the Maryborough Formation or the upper part of the Grahams Creek Formation, i.e. approximately the top of the Grahams Creek Formation.

In this study, all data of the above three surveys were re-examined and re-mapped in conjunction with the analysis of the new Survey 91 data set. The nomenclature of the three prominent horizons was retained (as A, A1 and B). However, the stratigraphic levels of A and A1 were revised as:-

A: top of Lower Unproductive member of the Burrum Coal Measures
A1: top of Maryborough Formation.

These amendments were made on the basis of, (i) revised interpretation of the 1963 Shell data in the Bundaberg area and to the northwest of this area (some of the reflector horizons appear to have been mis-identified), and (ii) improved match in correlating reflectors between onshore and offshore data sets.

Three other major or significant seismic horizons were also mapped in this study:-

- horizon U, base of the Cainozoic section (i.e. top of Maryborough Basin or older rocks) in Hervey Bay,
- horizon C, the base of a sub Maryborough Formation sequence (which may correspond to all or part of the Grahams Creek Formation), and
- a deep 'basement' horizon, C1.

© Australian Geological Survey Organisation, 1994

CAPRICORN AND NORTHERN TASMAN BASINS

Five major seismic sequences, A-E, have been identified in the Capricorn Basin (Table 2). They are shown schematically in Figure 9. The basal unconformity and the four unconformities separating the sequences have been assigned tentative ages on the basis of well correlations, known regional unconformities and tectonic considerations. The ages are, (i) Late Cretaceous, (ii) Early Paleocene, (iii) Early Eocene, (iv) late Middle Eocene and (v) Early Oligocene.

The unconformities are represented by seismic horizons designated as follows:-

TB (top B)	Early Oligocene
TC (top C)	late Middle Eocene
TD (top D)	Early Eocene
TE (top E)	Early Paleocene
BE (base E)	Late Cretaceous.

As indicated in Figure 9, mega-sequence B consists of two sub-sequences - a lower shallow marine unit and an upper deltaic unit. The sequence boundary between the two has been designated as horizon MB (mid B).

TA (top A) is the seafloor. TB is equivalent to U in the offshore Maryborough Basin area (Hervey Bay and southeast of Fraser Island); it also correlates with reflector S4 of Marshall (1977).

A pronounced sub-planar erosional unconformity is present within the Cainozoic sediment wedge beneath the continental shelf off Fraser Island. The unconformity extends right across the shelf, truncating older Cainozoic strata beneath the outer shelf and pre-Tertiary bedrock towards the mainland shore. This unconformity, designated TAA, is correlated with reflector S3 in the Capricorn Basin (Marshall,1977) and a weathered zone at 209 m depth in GSQ Sandy Cape 1-3R (Grimes, 1982 and 1992; Palmieri, 1984); it corresponds to the regional middle-late Miocene unconformity (Chaproniere et al., 1990).

The sequences represent distinct phases in the evolution of the Capricorn Basin:-

Rift-phase (Late Cretaceous - Early Paleocene) sequence - Sequence 'E'
This sequence is localized in down-faulted basement structures, particularly half-grabens - which have been filled by as much as 2000 ms twt of sediment. The reflection configuration is slightly to strongly divergent. The sequence is believed to be mainly continental, comprising fluviatile and alluvial fan deposits. Conglomerates and redbeds were the basal units intersected in the wells at the northern end of the basin. The upper part of the sequence may include restricted shallow marine facies.

Late rift-phase (Late Paleocene - Early Eocene) sequence - Sequence 'D'
Though development of this sequence was also controlled largely by basement structure, its influence was less, with the result that deposition was more widely distributed. Rifts were sites of maximum deposition, and received up to about 1000 ms twt of sediment; elsewhere deposition was variable but averaged about 300 ms twt. Reflectors in the sequence are divergent to sub-parallel. Sedimentation is interpreted as mixed shallow marine / terrestrial.

© Australian Geological Survey Organisation, 1994

Early thermal sag phase (Early - Middle Eocene) sequence - Sequence 'C'
This sequence is characterized by strong, parallel to sub-parallel internal reflectors. It gradually thickens towards the southern part of the Capricorn Basin, where some ?shelf-edge prograding packages lie within the sequence. Average thickness is about 450 ms twt. The upper surface is erosional, with effects of erosion most pronounced in the southern part of the basin, particularly on the margins where subaerial/wave-base erosion truncated much of the sequence, leaving a strong angular unconformity. The tectonic event that produced broad uplift also reactivated basement faults resulting in pop-up of fault blocks, which were subsequently bevelled to base level by erosion.

Though the Capricorn Basin was at a high latitude in the Early Eocene, surface-water temperature was relatively high during this period, about 20°C (Davies et al., 1989; Feary et al., 1991) - warm enough to support growth of sub-tropical carbonates and perhaps even reefs. This transgressive sequence is therefore likely to contain a significant biogenic carbonate component. With water depth increasing to the south, a corresponding progression of facies in this sequence is expected - ranging from near-shore in the northern part of the Capricorn Basin, to mid-shelfal in the centre and shelf-edge in the southern part of the basin adjoining the newly created Tasman Sea.

Post tectonic structural reactivation (mid-Late Eocene) sequence - Sequence 'B'
Though only about 300-400 ms twt thick, this sequence is significant because it includes a major deltaic/lagoonal regressive facies containing quartzose sandstones, locally abundant lignites and carbonaceous shale, as well as some beds of anhydrite. A thin shallow-marine sandstone unit forms the base of the sequence. The sequence is about 280 m thick at Capricorn 1A and 450 m thick at Aquarius 1. It was initially dated as Late Oligocene (Hekel, 1973; Ericson, 1976), but this has now been revised as Middle-Late Eocene (Chaproniere et al., 1990). The regional Oligocene unconformity is the upper boundary. Reflections are strong, with parallel to wavy configuration. The deltaic facies may extend from Capricorn 1A as far southeast as the centre of the Capricorn Basin. The seaward limit of a prominent, 280 ms twt thick, prograding sediment wedge is seen in the data at this point. The top of the prograding sediment package lies about 800 ms twt sub-bottom.

Late sag / rapid regional subsidence (Late Oligocene - Recent) sequence - Sequence 'A'
This uppermost sequence is about 800 ms twt thick over the northern and central part of the Capricorn Basin, but thins rapidly at the southern end of the basin, where ocean currents have prevented deposition and caused erosion. The sequence is completely absent in the large submarine valley that leads to abyssal depths in the northwest corner of the Tasman Basin. Reflectors are mainly parallel to sub-parallel, but are disrupted over much of the basin (particularly the central part) by pervasive compaction faulting. Well data indicate that this sequence is entirely marine, and that some variations in water depth accompanied deposition. It is essentially of carbonate lithology - calcareous claystones, marls and bioclastic limestones.

SEISMIC REFRACTION ANALYSIS

Sonobuoy data were recorded on 10 segments of the seismic reflection lines (Figure 2). The aim was to establish the vertical velocity structure of the sub-bottom.

© Australian Geological Survey Organisation, 1994

The velocity/depth analysis was simplified by assuming a horizontally-layered velocity structure and calculating refractor depths from intercept times. Drift of the sonobuoys, particularly in currents of 2-3 knots commonly encountered on the shelf southeast of Fraser Island, was a possible source of error in determination of source-receiver offset, and hence refractor velocity. To minimize the effect of such uncertainty, refractor velocities at each site were taken as the mean of two calculated values, (1) the velocity calculated assuming zero sonobuoy drift and (2) the velocity determined using the direct water arrival as reference and assumed to have a 'standard' velocity of 1500 m/s. The results of the analyses at all 10 sites are provided in Table 3; included is a geological interpretation of the various refractors. The data from sonobuoy 13 (in water depth greater than 4000 m) are of limited usefulness because of noisy signal.

Valuable refraction information was also available in the MCS shot-gathers recorded over the shallow-water parts of the survey area, including Hervey Bay and the inner continental shelf southeast of Fraser Island. Sub-Cainozoic bedrock velocities in the offshore Maryborough Basin are particularly useful for interpretation since offshore well control is absent.

Shot records from Hervey Bay and the shelf off Fraser Island were examined and velocities of the sub-Cainozoic refractor measured. Every 50th shot record was selected for analysis, thereby providing refraction data at 2.5 km intervals. Measured velocities are apparent velocities since reverse profiles were not available. However, since the Cainozoic strata are generally near-horizontal (at least over distances in the order of a streamer length) the apparent velocities are a good approximation to the actual refraction velocities. The contoured refraction data are presented in Enclosure 4.

The contours in the Hervey Bay area display a pronounced NNW trend, consistent with the local structural trend of the Maryborough Basin as mapped in the reflection data (Enclosures 8-10). Velocities are relatively low (~3000 m/s) in the axial zone of the major offshore syncline where the Burrum Coal Measures subcrop, and increase to the ENE towards the Bunker Ridge. Bedrock velocities on the Bunker Ridge are mainly over 4600 m/s and range to about 5600 m/s. Interpreted subcrop geology and refraction velocities appear to be well correlated, as indicated below.

Burrum Coal Measures (Productive member): 2900-3400 m/s
Burrum Coal Measures (Lower Unproductive member): 3400-3800 m/s
Maryborough Formation: 3800-4500 m/s

No data are available for the latest Triassic - mid Jurassic sediments of the Duckinwilla Group. Bedrock with very high refraction velocities, 4600-5600 m/s, probably represents Grahams Creek Formation (and subvolcanic equivalents), very tight clastic sediments of the Maryborough Basin, or late Paleozoic - Triassic basement (metasediments or granites).

Limited velocity information for the lithostratigraphic units of the Maryborough Basin is available from earlier surveys. Velocity profiles were shot by Shell near the Cherwell 1 and Susan River well sites during the 1963 Pialba - Fraser Island Survey (Bruce and Thomas, 1964). An interval velocity of 3000 m/s was determined for the lower Burrum Coal Measures and 4120/4600 m/s for the Maryborough Formation (near Cherwell 1), and 4000 m/s for the Maryborough Formation (near Susan River).

© Australian Geological Survey Organisation, 1994

Velocity surveys in the Gregory River 1 and Gregory River 2 wells also provide control on interval velocities. Data from the Gregory River 1 well (Shell Development, 1967) are -

Lower Burrum Coal Measures		3000 m/s
Maryborough Formation	(upper pelitic member)	3000/3840 m/s
" "	(upper sandy member)	3840/4210 m/s
" "	(lower pelitic member)	4210/3640 m/s
" "	(lower sandy member)	4150 m/s

The velocity survey in the last well to be drilled, Gregory River 2, provides further information on typical interval velocities for the various lithostratigraphic units penetrated:-

Burrum Coal Measures (lower)	3400 m/s; 2900 m/s near base
Maryborough Formation	
Caramar Siltstone	2750 m/s
Theodolite Siltstone	3300 m/s
Isis Arenite	3700-4000 m/s
Goodwood Mudstone	3900-4400 m/s
Woodgate Siltstone	3800 m/s
Cherwell Mudstone	3100-3600 m/s
Gregory Sandstone	4500 m/s
Grahams Creek Formation	4700 m/s

Guided by velocity data available from the various sources outlined, interval velocities adopted for time to depth conversions in this study are as follows -

Burrum Coal Measures (Productive member, i.e. above A)	3000 m/s
Burrum Coal Measures (Lower Unproductive, i.e. A-A1)	3400 m/s
Maryborough Formation (i.e. A1-B)	4050 m/s

In the case of the Capricorn and northern Tasman Basins, the following interval velocities have been adopted for conversion of time data to depths or thicknesses. The velocities were derived mainly from velocity surveys in the Capricorn 1A and Aquarius 1 wells and from refraction data; stacking velocities were a secondary source of information. Some of the sequences, particularly rift fill sequences D and E which contain such diverse lithologies as conglomerates and claystones, could exhibit significant variation in interval velocity from one part of the basin(s) to another.

Seawater	1500 m/s
Sequence A	2250 m/s
Sequences B+C	2600 m/s
Sequences D+E	3300 m/s.

Where horizon TD could not be mapped, the interval velocity for B→E (inclusive) was taken as 2900 m/s. In a couple of places, only the BE (basement) horizon could be mapped with any certainty; in these locations an interval velocity of 2500 m/s for the overlying section was assumed in calculating depths.

© Australian Geological Survey Organisation, 1994

SEISMIC MAPPING RESULTS: DESCRIPTION AND DISCUSSION OF BASIN STRUCTURE

The main products of the seismic reflection mapping are the structure, time thickness and isopach contour maps presented as Enclosures 7-27. Conversions of reflection time data to depths and thicknesses were made using adopted interval velocities, as discussed in the previous section (Seismic Refraction Analysis).

All contour maps were produced initially using the Petroseis basin mapping package (Petrosys Pty Ltd, Norwood, South Australia). Many of the contour maps that cover the Hervey Bay area were refined by hand to constrain contours to better reflect available additional geological control - mainly onshore field data. The Capricorn and northern Tasman maps were retained as machined contoured versions. The computer-drawn contours for this offshore region appear to be quite satisfactory, in that they honour the basic data and are geologically consistent. Some minor distortion of the contours is inevitable in areas of patchy or sparse data. To retain full integrity of these maps and to allow future recontouring as new data become available, posted values of the basic data are displayed.

To further illustrate the structural and stratigraphic framework of the basins, the contour maps are supplemented by selected key interpreted seismic profiles (Enclosures 28-33).

A map of bedrock structure beneath the continental shelf southeast of Fraser Island was produced (Enclosure 34).

MARYBOROUGH BASIN - HERVEY BAY AREA

CONTOUR MAPS

Time structure, base Cainozoic section (Enclosure 7)

The time structure contours in the Hervey Bay area represent top of bedrock, i.e. Maryorough Basin and older units, and possibly also massive Tertiary basalt flows. Depth to bedrock increases towards the shelf edge. In nearshore southwestern Hervey Bay, bedrock depth is about 50 ms twt (about 50 m), while near the shelf edge depth to bedrock increases to just over 450 ms twt (about 550 m). The latter figure is supported by drilling results from the stratigraphic hole at the northern end of Fraser Island (GSQ Sandy Cape 1-3R). In the nearshore area of western Hervey Bay, a local increase in bedrock depth is mapped just northeast of Bundaberg, and is expressed as an embayment in the 200 ms twt contour. This structural change may reflect an offshore extension of the low-relief, onshore Bundaberg Trough (Robertson, 1990), which is probably early Tertiary in age.

Time structure, horizon A (top Lower Unproductive member of Burrum Coal Measures) (Enclosure 8)

The gross structure on the top of the Lower Unproductive member is seen as a NNW-trending synclinorium. Offshore, beneath western Hervey Bay and farther to the NNW, the structure is relatively simple and consists of a broad NNW-trending syncline. The ENE limb of this syncline is relatively steep with a dip of about 17°. Onshore, the structure is more complex and consists of a series of medium to large synclines and anticlines. The Burrum

© Australian Geological Survey Organisation, 1994

Syncline is a large, relatively simple structure. The strata adjacent to the Bullyard Fault (on the western boundary of the basin) dip very steeply and may be overturned in places.

Time structure, horizon A1 (top Maryborough Formation) (Enclosure 9)
The structure on horizon A1 is similar to that on horizon A. Steep dips and possible overturning of strata occur on the southwestern margin of the basin. Anticlinal closures are mapped at the Gregory River 1 and 2 well sites, 4 km northwest of the Cherwell 1 well site and about 6 km south of Bundaberg. The structure south of Bundaberg is not well-defined on its northeastern side because poor seismic control; the area of closure on this structure could be up to 70 km^2.

Time structure, horizon B (base Maryborough Formation) (Enclosure 10)
The main structural pattern for base Maryborough Formation (top Grahams Creek Formation) is similar to that of horizons A and A1. The major NNW-trending syncline off the western coast of Hervey Bay reaches maximum time depth of 2.95 s twt to the northeast of Bundaberg. Local structural highs are present at the Gregory River 1 and 2 well sites, 3 km northwest of Cherwell 1 and 6 km south of Bundaberg. Small culminations may be present beneath the nearshore area of Hervey Bay where the horizon flattens in the trough of the major syncline. The Susan River well appears to be located on the crest of a NNW-plunging fold.

Time structure, horizon C (base sub Maryborough Formation sequence - ?Grahams Creek Formation) (Enclosure 11)
The horizon dips steeply to the southwest from beneath the middle of Hervey Bay to beneath the nearshore zone on the western side of the Bay. It starts to flatten out at a time depth of about 3.0 s twt and extends to a depth of at least 3.4 s twt (about 6.5-7 km).

Time structure, 'basement' horizon (Enclosure 12)
This 'basement' reflector culminates beneath the centre of Hervey Bay at a time depth of a little less than 1.0 s twt and deepens to the southwest, reaching 4.6 s twt (about 9-10 km) just off the western coast of the Bay. It may represent the upper surface of a granitic intrusion.

Lower Unproductive member of Burrum Coal Measures (horizon A-A1) time thickness (Enclosure 13)
The thickness of this unit is fairly uniform over the study area, suggesting that deposition took place under conditions of regional, rather than localised, subsidence. The unit is mainly 500-650 ms twt (850-1100 m) thick, though in the extreme north it thins to about 350 ms twt.

Maryborough Formation (horizon A1-B) time thickness (Enclosure 14)
The depocentre of the Maryborough Formation is in the southern part of the map area - in the Point Vernon area or perhaps even farther to the southeast. Maximum time thickness is about 1200 ms twt (about 2500 m). The formation thins westward to about 400 ms twt (about 800 m). Thinning to the northeast is less pronounced.

© Australian Geological Survey Organisation, 1994

Sub Maryborough Formation sequence (?Grahams Creek Formation), horizon B-C time thickness (Enclosure 14)

This unit thickens (from about 200 ms twt to at least 800 ms twt) in a southwest/WSW direction beneath the western part of Hervey Bay. Very rapid thickening is observed beneath the mid southern part of the bay. The unit is characterised by a divergent reflection configuration and is interpreted as comprising rift-fill, such as alluvial fan deposits.

Structure contours, horizon A1 (top Maryborough Formation) (Enclosure 15)

As expected, the structure contours in this map closely resemble the time structure contours of Enclosure 9. Maximum depth to the top of the Maryborough Formation occurs in the trough of the broad NNW-trending syncline located off the western coastline of Hervey Bay. The deepest point lies northeast of Bundaberg at about 3150 m depth. Anticlinal closures are mapped at the Gregory River 1 and 2 well sites, 3.5 km WNW of the Cherwell 1 well site and 6 km south of Bundaberg. A small closure also appears to be present 12.5 km northwest of Gregory River 2.

Structure contours, horizon B (base Maryborough Formation) (Enclosure 16)

The structural features in this map mimic those seen in the time structure map (Enclosure 10). Maximum depth of the base of the Maryborough Formation is 4950 m, attained about 6 km offshore to the northeast of Bundaberg

SIGNIFICANCE OF SEQUENCE TIME THICKNESS VARIATIONS

The mapped time thicknesses of the basin sequences provide information on the depositional history. The oldest sequence that can be mapped, at least over part of the basin, is B-C. It underlies the horizon marking the base of the Maryborough Formation (B) and so probably represents Grahams Creek Formation. It is characterized by divergent reflector patterns and rapid basinward increase in thickness; an increase in time thickness from 200 to 800 ms takes place over a relatively short distance (Enclosure 14). The variation in time thickness of the Maryborough Formation (Enclosure 14) is less dramatic, but still appreciable, ranging from 400 ms in the northwest to 1200 ms at a local depocentre beneath the southern shore of Hervey Bay. Time thickness contours for the overlying Lower Unproductive member of the Burrum Coal Measures display little variation (Enclosure 13). The time thickness of the unit is a fairly uniform 500-600 ms. These results suggest that Early Cretaceous basin development began with initial rapid localized subsidence and deposition, perhaps in a northwest-oriented graben, followed by a period in which there was a gradual decrease in the subsidence rate and more regional downwarp.

SEISMIC PROFILES

Maryborough Basin interpreted seismic profiles, onshore to offshore correlations - lines S-39 & M-7030, S-33 & M-7026 and S-32 & 091/23 (Enclosure 28)

The three composite sections in Enclosure 28 illustrate, (i) the structure of the Maryborough Basin in cross-section, and (ii) the correlation of seismic horizons from the onshore part of the basin (where there is well and outcrop control) to the offshore part of the basin. The S-39 & M-7030 section is representative of the northern Maryborough Basin,

© Australian Geological Survey Organisation, 1994

while the S-33 & M-7026 and S-32 & 091/23 sections portray the structural configuration of the central Maryborough Basin.

S-39 & M-7030
The structure in the Early Cretaceous units of the basin is essentially a broad asymmmetric syncline with its steeper limb to the northeast - the trough axis is located about 30 km offshore. The steeper northeast limb shows reverse faulting associated either with the folding episode or later strike-slip movements. The pre Maryborough Formation section appears to occupy a graben beneath the syncline. As is the case elsewhere in the Hervey Bay area, the Maryborough Basin sequence is unconformably overlain by a blanket of seaward thickening Cainozoic sediments up to several hundred metres thick.

S-33 & M-7026
The data gap between the onshore and offshore profiles in this case is only about 8 km. The section is similar to that farther north, though here the main structure is more of a synclinorium. Tighter folding has produced major anticlines such as the Cherwell and Gregory in the western onshore part of the basin and smaller fold structures in the thicker section offshore. Again, we see high-angle faulting on the northeastern flank. The faults may be part of a flower structure produced by syn- or post-folding strike-slip movement.

The basin appears to extend to about 4.6 s twt, i.e. 9-10 km depth.

S-32 & 091/23
The deep 'basement' horizon C1 is arched beneath the northeastern margin of the basin. The 'basement' surface is broken in places by what appear to be normal faults. The immediately overlying section may include Duckinwilla Group (Tiaro Coal Measures and Myrtle Creek Sandstone).

As is the case farther to the northwest, the northeastern limb of the main syncline is disrupted by a system of faults produced by compressional or transpressional movement.

The Gregory River 1 well is located on the Gregory Anticline, seen here as a faulted anticlinal structure bounded to the west by an east-dipping reverse fault.

Offshore Maryborough Basin (Hervey Bay) interpreted seismic profiles oriented in dip direction - lines 091/21, 091/22P1, 091/15 and 091/16 (Enclosure 29)
These Survey 91 profiles portray the structure of the offshore Maryborough Basin in Hervey Bay and the basin's structural relationship to the Bunker Ridge.

091/21
The line 091/21 profile shows a section typical of the offshore northern Maryborough Basin. The Maryborough Basin units have been folded into a deep synclinal structure. The Early Cretaceous Burrum Coal Measures and Maryborough Formation attain a combined thickness of about 4.3 km. Faults, with mainly small displacement, are present - particularly in the lower part of the section.

The steeply dipping beds of the Burrum Coal Measures and the Maryborough Formation have been truncated by erosion. The unconformity is overlain by several hundred metres of mid-late Cainozoic sediments - shelfal carbonate and quartz sands underlain by fluviatile

© Australian Geological Survey Organisation, 1994

deposits, possibly including Elliott Formation or equivalents. Local relief of about 100 m in horizon U at the Bunker Ridge may be erosional, but could also represent the top of Tertiary basalts.

The pre-Tertiary section beneath the Bunker Ridge is largely devoid of prominent reflector horizons. Some weak, dipping events can be discerned, however.

091/22P1

The Maryborough Basin strata dip steeply southwest into the trough of the main Hervey Bay syncline. As seen on other lines across the northeast limb of this syncline, significant faulting (mainly reverse faulting) has affected the limb. Fault development appears focussed at points of maximum flexure of the beds.

The 'basement' horizon C1 culminates towards the middle of the line, and then dips northeast on approach to the Bunker Ridge. An overlying uncorrelated reflector also dips northeast. The section overlying C1 in this area may be largely Duckinwilla Group. Thin outliers of Maryborough Formation may be undetected in the seismic and could be present along synclinal trends beneath the unconformity at the base of the Tertiary.

091/15

The Maryborough Basin structure seen in this profile is similar to that of 091/22P1. The main differences are that the beds in the northeast limb of the main syncline dip less steeply and that there is no evidence of significant faulting. There is a suggestion of a broad syncline in the sub-Tertiary in the middle of the line. Apart from some indistinct uncorrelated dipping reflectors, no pronounced internal structure is evident in the Bunker Ridge. The northeast margin of the ridge is marked by a series of normal faults that step 'basement' down beneath the Capricorn Basin.

The erosional unconformity U at the base of the Tertiary is seen to be essentially planar with gentle dip northeast towards the Capricorn Basin.

091/16

In this profile, the 'basement' reflector C1 appears considerably disrupted by complex faulting. Though the structures are suggestive of mainly normal faulting (as indicated), the causative mechanism is not obvious because the structures are poorly resolved in the seismic. The broken surface of C1 may even be due to reverse faulting associated with a southwest-directed thrust at depth.

CONTINENTAL SHELF SOUTHEAST OF FRASER ISLAND (MARYBOROUGH / NORTHERN TASMAN BASINS)

The Maryborough Basin is present beneath Fraser Island and can also be traced beneath the continental shelf southeast of the island. However, correlation and mapping of Maryborough Basin seismic horizons beneath the shelf presents more difficulty than in Hervey Bay. This is because of the relatively poor seismic data quality in this area, the observed complex structural deformation and the absence of well control. As a result, production of structure contour maps for sub-Tertiary horizons was not undertaken for the

© Australian Geological Survey Organisation, 1994

shelfal region. Interpreted representative seismic profiles and a bedrock structure map are provided (see below).

CONTOUR MAPS

Time structure - Early Oligocene unconformity, shelf southeast of Fraser Island (Enclosure 17)

The contours define the bedrock (Maryborough Basin and older rocks) surface beneath the continental shelf. The Oligocene unconformity is not well defined in the seismic data beneath the continental slope because of the rugged topography and complex structure. Nevertheless, it is seen to descend steeply to the abyssal region of the Tasman Basin. Beneath the shelf, the unconformity surface is roughly planar and dips gently towards the shelf edge. Relief on this gently dipping, erosional surface may, in part, reflect river channel incision during the Early Oligocene eustatic sea-level low-stand and perhaps earlier periods of subaerial exposure in the early Tertiary.

Isopachs - post Early Oligocene section, shelf southeast of Fraser Island (Enclosure 18)

The thickness of the post Early Oligocene fluvial and shelfal deposits ranges from a few tens of metres close inshore to about 1600 m in places at the shelf edge. The deposits have developed maximum thickness in a band along the shelf edge in about 900 m of water. Canyons, that continue down the continental slope to abyssal depths, have deeply incised the deposits at the shelf edge.

SEISMIC PROFILES

Interpreted seismic profiles across the continental shelf southeast of Fraser Island - parts of lines 091/03, 091/05P2, 091/10 and 091/11 (Enclosure 33)

091/03

This profile intersects Maryborough Basin structures in the dip direction. Maryborough Basin reflectors are visible to a depth of 2.0 s twt (~4 km). The pre-Tertiary section has been deformed by folding and faulting. The folding is mainly gentle; faulting includes reverse faults. The large-scale folds have a wavelength of 10-20 km.

The Cainozoic cover sequence thickens towards the shelf edge. Both the base Tertiary unconformity (U) and the intra late Cainozoic (? late Middle Miocene) unconformity (TAA) are erosional with small, but distinct, relief.

091/05P2

This profile is oriented at oblique angle to the local structural trend. The folds are broad and relatively little disrupted by faulting. Several reverse faults cut the section, however. The mean visible thickness of the Maryborough Basin section is about 2.0 s twt (~4 km). Thickening at the northwest end of the profile may indicate that the basin deepens towards the coast and beneath Fraser Island.

091/10 & 091/11

Beds of the Maryborough Basin dip relatively steeply into a deep, faulted, NNW-trending synclinal structure located just out from Wide Bay. Major Maryborough Basin structures that have been mapped to the northwest (eg. Urangan Synclinorium, Susan Anticline and

© Australian Geological Survey Organisation, 1994

Burrum Syncline) appear to converge southeast towards this structure. Adjacent onshore geology and stratigraphic drilling permit tenuous stratigraphic identification of the seismic reflectors.

Intense reverse faulting has disrupted the section in places, particularly the steep northeastern limb of the main syncline. About 2.5 s twt (~5 km) of latest Jurassic(?) - Early Cretaceous section (Grahams Creek Formation, Maryborough Formation and Burrum Coal Measures) is present in the syncline.

Further complex geology is seen at depth. A deep reflector that extends to a depth of about 4 s twt (8-9 km) may represent basement. Section overlying basement would include sediments of the Duckinwilla Group. Strong reflectors that lie at a depth of about 3.3 s twt beneath the main syncline may represent igneous bodies.

BEDROCK STRUCTURE MAP

Bedrock structure beneath the continental shelf southeast of Fraser Island (Enclosure 34)
The sub-Tertiary strata beneath the shelf are folded and faulted, forming a series of synclinal and anticlinal structures. The fold axes and associated structures (reverse faults) show a northwest to north trend.

Maximum thickness of latest Jurassic(?) - Early Cretaceous Maryborough Basin section (about 2.5 s twt, i.e. 5 km) occurs in a deep syncline in the Wide Bay / southern Fraser Island area. The presence of thick sedimentay section in this area is supported by an associated flat magnetic field, a pronounced gravity low, and relatively low refraction velocities. Elsewhere beneath the shelf, the visible sub-Tertiary section is typically 1-2 s twt (2-4 km) thick.

The structure beneath the shelf edge and continental slope is dominated by strong normal faulting, mostly oriented sub-parallel to the margin (i.e. north-south). The rifted margin is narrow (about 35 km) and steep (more than 4 km relief). Margin collapse has produced a multitude of fault blocks beneath the slope. Individual blocks appear to be of limited extent in the strike direction, with 20 km being about the maximum dimension in this direction.

The rift-related structures are restricted almost entirely to the narrow zone along the shelf edge and continental slope. Some minor landward (westward) encroachment of such structure is seen beneath the outer shelf east of Noosa adjacent to an embayment in the seafloor. About 2.5 s twt of syn- and post-rift sedimentary section has been preserved within a graben. Landward-penetrating rift structures may have developed preferentially at this locality on the margin since this area lies along the NNW axial trend of the Maryborough Basin. The observed graben development (and creation of a seafloor embayment) was probably the result of extensional forces associated with Tasman rifting interacting with structure imparted during the mid Cretaceous deformation episode.

© Australian Geological Survey Organisation, 1994

CAPRICORN AND NORTHERN TASMAN BASINS

CONTOUR MAPS

Time structure, horizon TB (top sequence B, Early Oligocene unconformity) (Enclosure 19)
The unconformity surface lies at shallow depth beneath the continental shelf in the vicinity of Fraser Island and along all the margins of the Capricorn Basin except the southeastern. It deepens towards and into the northern Tasman Basin, where it lies at time depth of up to 7.0 s twt. The surface has been relatively downwarped along the axial zone of the Capricorn Basin. In other words, the axial region of the basin has subsided at a faster rate than the northeastern and southwestern flanks since the Late Oligocene.

Time structure, horizon TC (top sequence C, near mid Eocene) (Enclosure 20)
Within the Capricorn Basin, the TC surface is relatively smooth and in the shape of a trough that plunges toward the southeastern end. The surface descends steeply into the Tasman Basin. The axis of the surface coincides with that of the Capricorn Basin.

TC is an erosionally planated surface at the margins of the Capricorn Basin. It has minor relief due to structural reactivation, particularly in parts of the basin which were in relatively deep water at the time of the tectonism and so were not directly affected by subsequent subaerial erosion. The horizon lies at about 1700-1800 ms twt in the central part of the Capricorn Basin.

Time structure, horizon BE ('basement') (Enclosure 21)
'Basement' of the Capricorn and northern Tasman Basins is, for mapping purposes, here taken to mean rocks of pre Late Cretaceous age and apparent oceanic crust (early Tertiary).

The underying structure of the Capricorn basin is complex. The basement faults are predominantly normal, vary somewhat in strike direction and are of relatively short strike-length. Most individual faults appear to be less than about 30 km in length. The relatively wide spacing of seismic lines across the basin is not conducive to detailed mapping. Nevertheless, it appears that the structural fabric, as defined by strike of 'basement' faults, has a NNW to north trend. This is at slight variance to the orientation of the basin axis (as determined by the gross basin geometry), which is aligned approximately northwest.

In the deep-water area of the Tasman Basin, depth to 'basement' is typically 7500-9500 ms twt.

Time thickness, sequence A (Late Oligocene - Recent) (Enclosure 22)
In the Capricorn Basin, the areas of thickest accumulation of sequence A are the central and northern parts of the basin. Sequence A is 800-1000 ms twt (about 900-1125 m) thick in these areas.

At the southeastern end of the Capricorn Basin, sequence A has been significantly affected by erosion and non-deposition. The floor of a large submarine valley located here has been eroded and incised by a system of deep channels. Confluence of water masses flowing from the Capricorn Channel and adjacent shelves down to abyssal depths of the northern Tasman Basin may have generated (and ?continues to generate) the strong bottom currents

© Australian Geological Survey Organisation, 1994

responsible for the erosion. An area up to 1600 km² in size may be devoid of Late Oligocene and younger sediment cover, or have no more than a veneer of such cover. The extensive seafloor exposures of older strata of the Capricorn Basin likely to be found here offer an excellent opportunity for geological sampling of older strata of the Capricorn Basin. At present there are virtually no geological data on lithostratigraphy and environments of deposition from the southern part of the basin.

Sequence A shows a general increase in thickness in the downslope direction across the continental margin. The thickness varies significantly along the upper continental slope, but is typically several hundred metres; at abyssal depths in the northern Tasman Basin, A has a thickness of about 1350 ms twt (about 1500 m).

Time thickness, Late Eocene deltaic sequence TB-MB (Enclosure 23)
This deltaic sequence is present as a broad sheet in the northern and central parts of the Capricorn Basin. Its elongate depocentre is roughly aligned along the basin axis. Maximum thickness of about 270 ms twt (350 m approximately) is developed in the area just south of Capricorn 1A and Aquarius 1 well sites.

Time thickness, Eocene shallow marine / deltaic section, sequences B+C (Enclosure 24)
In the Capricorn Basin, the depocentre of this succession trends northwest along the axial zone of the basin. Thickness increases to the southeast, attaining about 760 ms twt (about 1000 m) in the mid south of the basin. The section thins dramatically or is absent over the basement highs adjacent to the Tasman Basin. Uplift and erosion, or unfavourable depositional conditions (?strong currents) at the paleo shelf edge / upper continental slope are believed responsible for the absent or condensed section. A significant thickness (at least 1.7 s twt) of this succession has been deposited at the base of the continental slope in the northern Tasman Basin.

Sequences B and C undoubtedly comprise mainly paralic or shelfal facies over most of the Capricorn Basin. A transition to deep-sea slope and basin facies would be expected, however, at the southeastern end of the basin and out into the Tasman Basin.

Time thickness, sequences D+E (rift-phase section, Late Cretaceous - Early Eocene) (Enclosure 25)
The rift-phase sediments in the Capricorn Basin show a complex distribution pattern, which is largely a function of the complex rift structure that controlled early deposition. Maximum thickness was developed in the southeastern part of the basin. Here, up to 2700 ms twt (~ 4500 m) of rift-phase sediments were deposited. Deposition was initially mainly localised within grabens, but then became more widespread as subsidence became more regional.

A number of depocentres located in the central and northwestern parts of the basin contain in excess of 700 ms twt (~1200 m) of rift section.

Time thickness, total sedimentary section (Late Cretaceous - Cainozoic) (Enclosure 26)
Enclosure 26 is a map of observed time thickness, and therefore represents minimum time thickness. The actual total sediment time thickness above 'basement' could be greater. An area where this could be the case is the base of the continental slope in the Tasman Basin. Here the amount of down-faulted and ?rotated rift-phase section is not well defined in the

© Australian Geological Survey Organisation, 1994

seismic. Consequently, the mapped section in this zone represents essentially only the post-breakup deposits.

The sediment thickness pattern in the Capricorn Basin exhibits a complexity that is largely inherited from the complicated 'basement' structure. Because most post-rift deposition was in response to broad, regional downwarp, local depocentres in Enclosure 26 correspond to centres of early rifting, i.e. graben development. Half-grabens in the deep-water southeastern part of the basin contain up to 3700 ms twt of section.

In the northern Tasman Basin, thick post-breakup deposits underlie the lower continental slope. These deposits are typically 2800 ms twt thick in the depocentre adjacent to the margin; up to about 4000 ms twt could be present in places. Away from the margin and towards the centre of the Tasman Basin, the sediment thickness decreases to about 2000 ms twt or less. The true sediment thickness in the vicinity of the Tasmantid Seamounts is obscured by the apron of volcanics shed from and surrounding these large volcanoes.

Total sediment thickness, sequences A-E (Late Cretaceous - Cainozoic) (Enclosure 27)
This map, generated by converting time total thickness of Enclosure 26 to isopachs, has the same gross features of its parent map.

Maximun sediment thickness in the southeastern Capricorn Basin is about 5700 m, while in the northern part of the basin it is about 3500 m. The thicker sediment accumulations are localised at 'basement' graben. Though sediment thickness varies greatly throughout the basin, there is a general trend of increasing thickness from northwest to southeast. Typical thickness in the axial region of the basin varies from about 2000 m in the northwest, to about 2500 m in the central part to about 3000 m in the southeast.

Maximum accumulation of post-breakup deposits in the northern Tasman Basin occurs at the base of the continent slope. These deposits are 3500 to 5500 m thick. Sediment thickness in the central part of the northern Tasman is in the order of 2000 m.

SEISMIC PROFILES

Trans Capricorn Basin interpreted seismic profiles - lines 091/28, GBR-47, QP-4, 091/14 and 091/26 (Enclosure 30)

091/28
Line 091/28 is located in the northern part of the Capricorn Basin and ties the Capricorn 1A and Aquarius 1 wells. The profile shows major half-graben development at the Aquarius 1 site and also just east of the Capricorn 1A site. Minor compressional or transpressional reactivation of 'basement' faults has produced minor high-angle faulting that extends upwards through the section to the TC horizon.

GBR-47
This line, located in the central Capricorn Basin, crosses a large graben. Low-angle reflectors within 'basement' dip beneath the graben. These reflectors may originate from strata within an underlying older basin (?Maryborough Basin equivalent) or may be of structural origin - perhaps thrust-related structures reactivated by crustal extension.

© Australian Geological Survey Organisation, 1994

QP-4

Line QP-4 crosses the central part of the Capricorn Basin. 'Basment' has been extensively disrupted by normal faulting. A large half-graben is located at the extreme southwestern end of the line, while a smaller half-graben of opposite sense, is present on the other side of the basin. Apart from the master faults associated with these structures, most of the faulting seen on this line has relatively small throw. The rift structures seen in the profile suggest limited extension over a broad zone and, apart from the half-grabens, comparatively little rift-basin development.

Some seafloor erosion and channel incision are evident in the middle of the basin.

091/14 & 091/26

Profiles of lines 091/14 and 091/26 have been combined to produce the composite profile across the southeastern Capricorn Basin shown in Enclosure 30.

The profile shows development of two main grabens within 'basement'. One of these, a half-graben, is located in the middle of line 091/14, while the other structure is located in the middle of line 091/26. The latter is underlain by a series of infra-'basement' reflectors that have moderate-shallow northeast apparent dip. They appear to be structural in nature - perhaps old thrusts , but could also represent strata of an underlying older basin.

Except where rifting has produced some disruption, horizon BE is seen to be remarkably planar. This is particularly obvious towards the northeastern end of this profile. It appears that the 'basement' surface was originally horizontal, probably a peneplain. Subsequent rifting broke this surface up, tilting many of the larger fault blocks basinward.

Mid Eocene reactivation produced both normal and reverse faulting of small displacement in sequence C and sub-strata. Mild folding accompanied the faulting. Unconformity TC is erosional at the margins of the basin. This was the result of uplift and subsequent subaerial/wave-base erosion. The southwestern margin of the basin appears to have undergone greater uplift than the northeastern margin. As seen at the southwestern end of the profile, the erosion that followed mid Eocene uplift removed the early Eocene section, much of the rift-fill and the top of an elevated, 5 km-wide basement block.

Seafloor relief caused by late Cainozoic erosion and channel incision is apparent along most of the line. This is consistent with the observed increase in such geomorphology towards the southeastern margin of the Capricorn Basin, where seafloor gradient increases.

Axial interpreted seismic profile (lines 091/29P1 and 091/29P2), Capricorn Basin (Enclosure 31)

This profile shows a strike section along the axis of the Capricorn Basin.

The 'basement' surface (BE) is mainly uneven and dissected by rift-related faults. Complex graben development is present in the middle of the profile; a graben is also located near the northwest end, adjacent to the Capricorn 1A well. Dipping reflectors are mapped within 'basement' towards the southeastern end of the profile. Local relief in BE is seen where a number of these reflectors terminate on this surface. The reflectors could well be of structural origin, i.e. represent faults. In this area, BE appears originally to have been an

© Australian Geological Survey Organisation, 1994

extensive, erosionally planated surface. Movement on these ?structures fragmented and displaced the surface. The ?structures may have been in place prior to Capricorn Basin rifting, and were reactivated by extension.

The Late Eocene deltaic sequence (TB-MB) extends across most of the Capricorn Basin, but pinches out towards the southeastern margin (near shot-point 13000).

Sequence A is about 1 km thick in the northern and central part of the basin. In these areas where it is relatively thick, small-scale pervasive compaction faulting has disrupted the carbonate section.

An inflection in the seafloor profile at shot-point 4300 in the central northern part of the Capricorn Basin close to the 200-m isobath represents the edge of a submarine bank. The seismic data indicate that this feature is of stratigraphic origin and not produced by faulting. Wilson (1967) noted that a series of troughs and low mounds are located at the base of the escarpment. Recovery in a dredge haul of what appeared to be mangrove root castes led Marshall (1977) to conclude that the 200-m 'trough' represents an ancient strandline.

Interpreted seismic profiles at and across the southeastern margin of the Capricorn Basin - lines 091/30, 091/31 and 091/13 (Enclosure 32)

Seismic lines 091/31 and 091/13 extend across the transform margin between the Capricorn and Tasman Basins.

091/30

One of the larger half-graben in the southern part of the basin is seen in profile 091/30. About 3.7 s twt of Late Cretaceous - Paleogene section is associated with the structure. Much of the Neogene marine section is missing in this area. Volcanics are exposed on the seafloor, and reactivation of basement structures has deformed and faulted the overlying section.

The volcanics are seen as large mounds on the seafloor - several hundred metres high and 3-5 km across. They sit on the Oligocene unconformity, and so are probably Late Oligocene or younger in age. They could be basalts of similar origin to that of the adjacent Tasmantid chain, in which case they are likely to be of Late Oligocene age. The volcanism may have been sourced by a mantle multiple-hotspot or hotline as discussed by Johnson et al. (1989). Onshore equivalents could be the trachytic volcanics at Waddy Point on Fraser Island dated as 30.6 Ma (Grimes et al., 1984).

The mid Eocene reactivation structures include reverse faulting and local anticlinal folding; there is also apparent thickening of beds across the faults. The structures suggest transpression, perhaps with dexteral movement.

The effects of the reactivation can be seen throughout the Capricorn Basin, but are most spectacular in the southern part of the basin.

091/31

A thick pile of post-breakup sediments has accumulated at the base of the continental slope. The sediments overlie the transform fault zone. Large blocks of 'basement' and synrift section have been down-faulted beneath the lower slope. The overlying deposits are up to

© Australian Geological Survey Organisation, 1994

3.5 km thick. They are probably mainly turbidites and slump material shed off the upper marginal slope. Slump structures occur on the steep slope.

About 3 km (2100 ms twt) of Capricorn Basin section lie to the north of a marginal basement high. Movement of the block probably took place as the eastern conjugate margin of the northern Tasman (now Kenn Plateau) slid past. After further uplift in the mid Eocene, this area probably remained close to sea-level until Late Oligocene. Since then the margin has subsided as much as 2.5 km.

091/13

A continental basement high underlies the margin. This structural configuration is similar to that seen in profile 091/31, except that here 'basement' is more intensely faulted. Rotated 'basement' blocks extend well beneath the continental rise, probably at least as far southeast as shot-point 5900. The primary transform fault at the margin, the Cato Fracture Zone, underlies these down-faulted blocks.

Up to 3.1 s twt of rift and post-rift section is present in the graben northeast of the marginal basement high.

The northwestern end of line 091/13 is one location where all five sequences (A-E) occur in the section. Mid Eocene structural reactivation has produced faulting and minor folding to the top of C (TC). The general high continuity and sub-parallel internal reflection character of sequence C in the Capricorn Basin suggests a shallow marine carbonate facies. Prograding sediment packages within C at around shot-point 13600 are probably shelf-edge deposits, which is corroborating evidence for increase in paleo water depths to the southeast across the margin. The likelihood of carbonates is enhanced by the fact that sea temperatures in the Early-Middle Eocene were relatively warm (Davies et al., 1989; Feary et al., 1991).

Seafloor erosion has exposed much of the mid Tertiary Capricorn Basin section in the submarine valley crossed by the mid northwestern part of line 091/13. A geological sampling program in this area would potentially have access to in-situ formations as old as Early Eocene.

Recorder Seamount, a large seamount of the Tasmantid chain, is only about 12 km off the southeastern end of line 091/13. Its apron of basaltic lavas and volcaniclastics can be seen in the section. The top of this apron lies a little above what has been interpreted as the regional Oligocene unconformity (TB). The age of the seamount has been estimated as 25±2 Ma (McDougall and Duncan, 1988; CPCEMR, 1991), which is consistent with the seismo-stratigraphic interpretation.

High amplitude events are common in the deeper part of the section beneath the northern Tasman abyssal plain. They are interpreted as volcanics - basaltic flows, dykes and sills - probably mid Tertiary and perhaps associated with the Tasmantid or adjacent mantle plumes that may have originated from the initial site of Coral Sea spreading (Sutherland, 1983, 1985 and 1991).

© Australian Geological Survey Organisation, 1994

BASEMENT STRUCTURE, CAPRICORN BASIN

The predominent structural trend appears to be roughly NNW. Basement structures are mainly seen as normal faults of relatively short strike length, 20 km or less. These extensional structures appear to be distributed over a 100 km wide zone beneath the basin. Maximum extension and rift development has occurred in the western half of the basin along a NNW-trending belt that is continuous with the base of the Tasman continental margin slope to the south off Fraser Island. This lineament must represent a major dislocation in the crust, being the site of northern Tasman breakup and incipient (but failed) breakup in the Capricorn Basin. The principal extension direction appears to have been WSW-ENE, parallel to the Cato Fracture Zone and adjacent basement ridge.

The structural complexity of Capricorn Basin basement suggests, however, that strike-slip movements may have accompanied early rift development, and pre-dated Late Cretaceous regional northeast-southwest extension associated with breakup and opening in the northern Tasman, Cato Trough and the Coral Sea.

A major strike-slip system may have been active in the ?Early-mid Cretaceous along a northwest trend through the Capricorn Basin, Whitsunday Basin (Gulf, 1974) and into the Queensland Trough. Basement fault patterns in the Queensland Trough suggest such movement with sinistral sense (Symonds et al., 1987; Symonds and Davies, 1988). Thus, as is indicated in the Queensland Trough, early basin development in the Capricorn Basin may have had a transtensional origin. The silicic Whitsunday Volcanics, active between 100-117 Ma (Ewart et al., 1990 and 1991), may have been erupted at a transtensional rift that formed part of the strike-slip system. The steep and narrow nature of the northern Tasman continental margin off Fraser Island suggests that breakup occurred on a pre-existing structure such as a major strike-slip fault.

EROSIONAL PRODUCTS OF UPLIFT

As much as several kilometres of Maryborough Basin section were removed by erosion since the mid Cretaceous. Where did the erosional products end up? No major contemporary or younger onshore basins, which may have acted as sediment sinks, are known to exist in the local region. That is, apart from the Eocene lacustrine oil shale basins located to the northwest. These are relatively small in volume, however.

Some of the sediment would have been incorporated in the shelfal wedge. Most of the missing section is believed to now lie at the base of the continental slope in the adjacent Tasman Basin. Here the Cainozoic post-breakup deposits alone are typically 3.5 km thick. These deepwater deposits overlie probable oceanic crust and highly extended continental crust, which may may include synrift sediments derived from the Maryborough Basin.

Late Cretaceous erosional products may also be found on the other side of the northern Tasman as synrift deposits split by seafloor spreading about 63 Ma ago. Sparker seismic data from the Kenn Plateau area suggest that a rift-valley sequence at least 2000 m thick underlies a post-breakup sequence of maximum 1000 m thickness (Willcox, 1981). Gravity lows elsewhere in this area also indicate other potential thick accumulations of sediment.

© Australian Geological Survey Organisation, 1994

BASIN EVOLUTION

MARYBOROUGH BASIN

The reconstruction of the eastern Australian margin (Figure 10), prior to its fragmentation in the Late Cretaceous to early Tertiary by rifting and seafloor spreading, highlights two significant points.

(i) The Maryborough Basin and New Caledonia were significantly closer in the mid Cretaceous. Plate convergence and associated folding episodes were active in the New Caledonia area during the Cretaceous to about 90 Ma. Low temperature metamorphism, two phases of folding and major strike-slip movement along the island axis took place during this Neo-Cimmerian Orogeny (Paris, 1981), which was coeval with the Rangitata Orogeny in New Zealand but persisted 10 Ma longer (Walley, 1992). This suggests that the deformation seen in the Maryborough Basin was linked to ?terminal convergent tectonism at a plate boundary located at New Caledonia.

(ii) Kenn Plateau fitted against the Maryborough Basin sector of the present margin. Parts of the original Maryborough Basin or equivalents may now be located on the Kenn Plateau or northern Lord Howe Rise. These large structures, though elevated above adjacent ocean basins, lie in moderately deep water - generally at depths of 1500 m or more. The eastern conjugate margin of the northern Tasman has yet to be investigated by modern MCS.

Figure 11 depicts the conceptual evolution of the central Maryborough Basin in the Cretaceous. The deep basin-forming structures are speculative since they are not well imaged by the seismic.

- In the Neocomian, a pre-existing NNW-trending fault system was reactivated by transcurrent movement which displaced basement and the latest Triassic - mid Jurassic sediment cover. Local transtension produced rotation of blocks on an ENE-dipping detachment linked to the master strike-slip fault. Acid-intermediate volcanism was associated with the rifting. A rift graben, the axis of which coincided roughly with the present southwest shoreline of Hervey Bay, rapidly filled with alluvial fan deposits of mainly volcanic origin.
- This was followed by a marine transgression and deposition of shallow marine clastic sediments as the crust was downwarped through thermal relaxation and sediment loading. By Albian time, deposition was taking place in a delta plain environment, with labile sediments being shed from a volcanic arc to the east. The basin may have been developing as a foreland basin at this time.
- Compression in the mid Cretaceous resulted in partial basin inversion and the folding of these units into a series of broad northwest-trending synclines and anticlines. Uplift related to (i) crustal shortening associated with this compressive episode, (ii) subsequent Tasman rifting, and (iii) igneous underplating, resulted in removal of up to several kilometres of section by erosion.

The ?Late Jurassic - Early Cretaceous development of the Maryborough Basin followed a cycle that is characteristic of tectonic periods in the New England Orogen. Each such period (Harrington and Korsch, 1985) commenced with an episode of plutonism and the creation of a basin containing volcanics of the same age as the plutons. The deposits that initially

© Australian Geological Survey Organisation, 1994

began to fill these basins were coarse clastics; as basin development continued the sediments passed upwards to finer-grained sediments and coal measures. Harrington and Korsch (1985) interpreted each cycle as beginning with an episode of subduction, which resulted in the generation of plutonic and volcanic rocks and the creation of a basin or basins. In this model, decline or end of subduction resulted in slower erosion and thus deposition of finer sediments and coals. The cycle repeated itself if subduction moved to a new site (generally to the northeast) or if relative motion across the plate boundary changed.

CAPRICORN AND NORTHERN TASMAN BASINS

The paleogeographic and, to lesser extent, tectonic development of the Capricorn and northern Tasman Basin region is illustrated in Figure 12 as a series of 6 maps, each covering successive periods of the basins' evolution.

End Late Cretaceous

By the end of the Late Cretaceous a NNW trending continental rift system had developed. The area was mountainous. Relatively narrow graben in the Capricorn Basin filled with products of erosion, including conglomerates. The sediments were deposited in alluvial fans and plains. Wrenching may have pre-dated or accompanied the early part of the main extensional phase, producing complex rift structure.

Late Paleocene / Early Eocene

Breakup in the Late Paleocene saw commencement of seafloor spreading and northward extension of the Tasman Sea into this area. Seafloor spreading failed to propagate into the Capricorn rift, being diverted northeast to the Cato Trough via the Cato Fracture Zone instead. Strike-slip movement on the transform produced some jostling of fault blocks in the adjacent Capricorn Basin. There was continuing minor extension and mainly general subsidence in the Capricorn, with some incursion of the sea likely.

Early Eocene

Seafloor spreading and extension ceased abruptly in the Early Eocene, the lithosphere cooled resulting in broad sag of the basins and marine transgression. Though the area was still at moderately high latitude, the climate was subtropical at the time. Carbonate-generating organisms thrived and extensive shallow marine sediment deposition took place. Turbidity currents carried shelf-edge accumulations to deep water.

Mid Eocene (~43 Ma)

In the mid Eocene, a compressive intraplate stress field, originating from major global plate reorganization and plate collision at the northeast edge of the Australian plate, produced uplift and erosion, as well as reactivation of basement faults and transpressive structures in the overlying section.

Latest Eocene - ?Early Oligocene

The tectonic event was short-lived. Thermal subsidence continued and marine sedimentation resumed much as before. However, by the end of the Eocene the climate had become much cooler and sea temperatures had dropped as a major glaciation developed in Antactica. Shoreline regression began through gentle regional upwarp and

© Australian Geological Survey Organisation, 1994

possibly eustatic fall in sea-level. A delta front advanced southeast as far as the centre of the Capricorn Basin. Quartz sands, lignites and anhydrites were deposited in a deltaic/sabkha environment. The mid Oligocene was a period of non-deposition or erosion, attributed, at least in the deeper marine areas to scouring by strong Antarctic bottom water currents and associated gyres.

Late Oligocene - mid Miocene

The opening of a deep-water passage south of Tasmania by mid Oligocene allowed development of the Circum-Antarctic Current and decoupling of cold-water flow northwards in the Tasman. This resulted in progressive re-establishment of the southward-flowing warm-subtropical East Australian Current, and increasing surface water temperatures as Australia continued to drift north. Fluvio-deltaic sedimentation in places on the margin soon gave way to marine carbonate and quartz sands as basin subsidence continued. Away from the shoreline, carbonate sedimentation predominated. The open shelf conditions that became established in early Miocene have persisted to the present.

This area drifted over the Tasmantid hotspot between ~30-25 Ma resulting in the construction of a series of large basaltic seamounts in the Tasman. Basalts of similar age occur on and beneath Fraser Island, and are also interpreted in the seismic data from the Capricorn and northern Tasman Basins. The volcanics may have been sourced by an extended mantle plume (multiple hotspots or hotline).

CONCLUSIONS

Survey 91 was the first geophysical investigation of the offshore southeast Queensland basins using modern MCS techniques since the early 1970's. As documented in this report, the new data from Survey 91, integrated with data of earlier surveys, have resulted in the first basin-wide structural and seismic stratigraphic analyses of the Maryborough (offshore and onshore) and Capricorn Basins.

In Hervey Bay, the seismic data show the Maryborough Basin to be a deep NNW-trending synclinal structure, the NNW flank of which subcrops in the middle of Hervey Bay at a prominent erosional unconformity. The unconformity is overlain by a wedge of mid-late Cainozoic sediments (and some basalts) that thickens seaward to a thickness of about 550 m north of Fraser Island. The Early Cretaceous Maryborough Formation (mainly shallow marine) and Burrum Coal Measures attain a combined thickness of 5 km in the major syncline that underlies the western half of Hervey Bay. A total basin thickness of up to 9-10 km is indicated in this area. There is no evidence of Burrum Coal Measures or more than relatively thin outliers of Maryborough Formation beneath the Cainozoic blanket along the Bunker Ridge to the northeast of the syncline.

Deformation in the mid Cretaceous produced folding and high-angle faults (normal and reverse). Uplift associated with this event and subsequent tectonism (including Tasman rifting and igneous underplating) elevated parts of the once more extensive basin by at least several kilometres. Peneplanation removed much of the basin section. The Maryborough Basin is thus an erosional remnant of a once much larger depositional basin.

© Australian Geological Survey Organisation, 1994

Anticlinal closures at the top of the Maryborough Formation were mapped in the onshore seismic data at the Gregory River 1 and 2 well sites, adjacent to the Cherwell 1 site, and just south of Bundaberg. The structure to the south of Bundaberg has not been drilled. The anticlinal structures appear to be bounded, at least partly, by high-angle reverse faults.

Survey 91 provides the first evidence of a substantial sedimentary section beneath the relatively wide continental shelf southeast of Fraser Island. 2-4 km of folded and faulted Maryborough Basin section is overlain by a wedge of mid-late Cainozoic shelf sediments ranging in thickness from few tens of metres close to shore (of the mainland) to about 1.6 km at the shelf edge. Refraction velocities of the older (pre-Tertiary) sediments are high, typically 4100±300 m/s, which suggests that they are indurated and probably accounts for the relatively poor seismic definition at depth over much of this area.

A deep, faulted synclinal structure was mapped in the Wide Bay area off the southern end of Fraser Island. It trends northwest and probably represents the southeastern extent of the major synclinorium in the Early Cretaceous units that is the main structural feature of the central Maryborough Basin. Burrum Coal Measures may comprise a significant part of the 5 km thick latest Jurassic(?) - Early Cretaceous section believed to occupy the synclinal structure. Elsewhere on the continental shelf, however, this unit is likely to be thin or absent - the observed section probably comprising Maryborough Formation and older units of the Maryborough Basin.

The wedge of mid Cainozoic and younger shelfal sediments southeast of Fraser Island overlies a seaward-dipping, erosionally-truncated platform of older rocks (largely Maryborough Basin units), and appears to have developed by margin sag. It increases in thickness from a few tens of metres nearshore (mainland) to about 1.6 km at the shelf edge southeast of Fraser Island. The sediment wedge contains thick seaward prograding sediment packages, and a prominent late Miocene erosional unconformity that is correlated with seismic horizon S3 (Marshall, 1977) in the Capricorn Basin. Correlation with stratigraphic hole Sandy Cape 1-3R suggests that the sediments comprise basal Late Oligocene - early Miocene fluvio-deltaics overlain by Miocene-Pleistocene quartz and carbonate sands deposited under shallow, open marine conditions.

Basement structures in the Capricorn Basin appear to be largely normal faults with a general NNW trend. The structural pattern is complex resulting in a mainly discontinuous series of rift basins of varying geometry. ?Early-mid Cretaceous wrench movements may have initiated the complex structure. The seismic data show evidence of shallow-dipping horizons within 'basement' beneath the central and southern parts of the basin. These may represent pre/syn-rift structure, early syn-rift volcanogenic deposits or strata of an older basin.

The first major volume of sediments to be deposited in the Capricorn Basin comprised continental rift-fill deposits of probable Early Cretaceous age. As the basin subsided, sedimentation became progressively more marine, with post-Oligocene deposits consisting almost entirely of marine carbonates. Maximum sediment thickness of about 5700 m occurs at a half-graben in the southeastern part of the basin. The section here is believed to comprise continental rift-fill grading upwards to Eocene marine sag-phase sediments.

Compression or transpression in the mid Eocene reactivated basement faults and produced minor faulting and folding in the overlying section, as well as uplift and subsequent erosion.

© Australian Geological Survey Organisation, 1994

This tectonic event is interpreted to be the product of intraplate stress generated as a result of major reorientation of plate rotation vectors at ~43 Ma.

Volcanics, probably basalts of Late Oligocene age injected along basement faults, form edifices several hundred metres high on the seafloor in the southern part of the Capricorn Basin. Extensive late Cainozoic erosion in this area has exposed Capricorn Basin strata at least as old as Early Eocene on the seafloor.

The deep structure of the Cato Fracture Zone at the northern end of the Tasman Basin is partly obscured by ?syn-breakup/hotspot volcanics and chaotic sedimentation. Large basement blocks have been downfaulted beneath the lower slope. Extended continental crust appears to underlie the western margin of the basin.

The seismic data show that vast amounts of sediment have spilled downslope into the deep-water of the Tasman Basin as fans, debris flows and turbidites since the basin formed. A thick Cainozoic sediment pile overlies apparent extended continental and oceanic crust at the base of both the northern and western marginal slopes. These post-breakup deposits are typically ~3.5 km (2.8 s twt) thick in a depocentre coinciding with the continental rise. The deposits may locally be as thick as 5.5 km. The deep-water section appears to contain volcanics that were probably sourced by the mantle plume, or extension of the plume, that created the Tasmantid Seamount chain post seafloor spreading. In the vicinity of large Tasmantid seamounts such as Recorder, seismic basement is effectively the top of the volcanic apron surrounding these edifices.

Sediment drifts, contourites and wavy bedding indicate that bottom currents had a strong influence on deep-sea sedimentation in the northern Tasman during the Neogene.

The steep marginal slopes have been sites of large-scale mass movements, including rotational slumping and submarine landsliding. The continental slope to the east and southeast of Fraser Island is particularly rugged and steep (7° mean slope). It is incised by numerous canyons up to several hundred metres deep. Cainozoic sediment cover on the slope varies mainly between 0-1 km.

ACKNOWLEDGEMENTS

Swath-bathymetric data from the 1990 PACRIM-WEST cable route survey were provided by OTC (Australia).

Jenny Bedford (AGSO) assisted with digitizing of contour maps. The figures and enclosures were drafted by Brian Pashley, Mirra Huber, Neville Montgomerie and Chris Fitzgerald of AGSO's Cartographic Services Unit.

Jim Colwell (AGSO) is thanked for critically reading the manuscript.

© Australian Geological Survey Organisation, 1994

REFERENCES

Affleck, J. and Landau, J.F., 1965 - Interpretation of an aeromagnetic survey, Swain Reefs area, Tenement 90P Great Barrier Reef, Australia. Gulf Oil Co., *PSSA Report* (unpublished).

Australian Gulf Oil Co., 1966 - Swain Reefs seismic project, Queensland, Australia (unpublished report).

Australian Gulf Oil Co., 1967 - Swain Reefs seismic project phase II - 1966, Queensland, Australia (unpublished report).

Baxmann, B., 1971 - Report of the interpretation of the reflection seismic survey 1970 in the Maryborough Basin - Hervey Bay area. Shell Development (Australia) Pty Ltd., SDA Report 117, *PSLA Report* (unpublished).

Benbow, D.D., 1980 - The petroleum prospects of the Great Barrier Reef region. *APEA Journal*, 20, 159-175.

Bruce, I.D., 1964 - Final report, Bunker Group marine seismic survey, Maryborough Basin, Queensland. Authority to Prospect 70P. Shell Development (Australia) Pty Ltd, SDA Report 37, *PSSA Report* (unpublished).

Bruce, I.D. and Thomas, J.S., 1964 - Final report, Pialba - Fraser Island seismic survey, Maryborough Basin, Queensland - Authority to Prospect 70P. Shell Development (Australia) Pty Ltd, SDA Report 24 (unpublished).

Burns, R.E., Andrews, J.E. et al., 1973 - Initial Reports of the Deep Sea Drilling Project, Volume 21. *U.S. Government Printing Office, Washington.*

Carlsen, C.T. and Wilson, T.C., 1968a. - Gulf-AOG Capricorn No. 1A, well completion report. *PSSA Report* (unpublished).

Carlsen, C.T. and Wilson, T.C., 1968b. - Gulf-AOG Aquarius No. 1, well completion report. *PSSA Report* (unpublished).

Chaproniere, G.C.H., Pigram, C.J., Symonds, P.A. and Davies, P.J., 1990 - The northeast Australian margin and adjacent areas - a biostratigraphic review and geohistory analysis. *Bureau of Mineral Resources, Australia, Record* 1990/7.

Cranfield, L.C., 1989 - New and revised Mesozoic stratigraphic units in the Maryborough 1:250 000 Sheet area, southeast Queensland. *Queensland Government Mining Journal*, 90, 163-174.

Cranfield, L.C., 1992 - Maryborough, Queensland. Australia 1:250 000 Geological Series, Sheet SG 56-6. *Department of Resource Industries, Queensland.*

Cranfield, L.C. (in prep.) - Stratigraphic units of the Maryborough Basin, southeast Queensland. Queensland Department of Resource Industries, *Queensland Geology 2 Series.*

Cull, J.P. and Conley, D., 1983 - Geothermal gradients and heat flow in Australian sedimentary basins. *BMR Journal of Australian Geology and Geophysics*, 8, 329-337.

CPCEMR, 1991 - Tectonic map of the circum-Pacific region, southwest quadrant, 1:10 000 000. Circum-Pacific Council for Energy and Mineral Resources. U.S. Geological Survey, Denver, Colorado.

Dalrymple, G.B., Lanphere, M.A. and Clague, D.A., 1980 - Conventional and ^{40}Ar-^{39}Ar and K-Ar ages of volcanic rocks from Ojin (site 430), Nintoku (site 432), and Suiko (site 433) seamounts and the chronology of volcanic propagation along the Hawaii-Emperor chain. Initial Reports of the Deep Sea Drilling Project, Volume 55. *U.S. Government Printing Office, Washington,* 659-676.

© Australian Geological Survey Organisation, 1994

Davies, P.J., Symonds, P.A., Feary, D.A. and Pigram, C.J., 1989 - The evolution of the carbonate platforms of northeast Australia. *In* Controls on carbonate platform and basin development, *Society of Economic Paleontologists and Mineralogists, Special Publication* 44, 233-258.

Day, R.W., 1983 - Geology and potential development of Queensland oil shales. *Queensland Government Mining Journal*, 84, 463-470.

Day, R.W., Cranfield, L.C. and Schwarzböck, H., 1974 - Stratigraphy and structural setting of Mesozoic basins in southeastern Queensland and northeastern New South Wales. *In* Denmead, A.K., Tweedale, G.W. and Wilson, A.F. (Editors), The Tasman Geosyncline - a symposium. Geological Society of Australia, Queensland Division, Brisbane, 319-363.

Day, R.W., Whitaker, W.G., Murray, C.G., Wilson, I.H. and Grimes, K.G., 1983 - Queensland geology: a companion volume to the 1:2 500 000 scale geological map (1975). *Geological Survey of Queensland, Publication* 383.

Derrington, S.S., 1981 - Gregory River No.2 well, Queensland. Well completion report. Department of Resource Industries, Queensland, unpublished report CR 10767.

Dooley, J.C., 1959 - Preliminary report on underwater gravity survey, Hervey Bay, Queensland. *Bureau of Mineral Resources, Australia, Record* 1959/68.

Doutch, H.F. and Nicholas, E., 1978 - The Phanerozoic sedimentary basins of Australia and their tectonic implications. *In* Scheibner, E. (Editor), The Phanerozoic structure of Australia and variations in tectonic style. *Tectonophysics*, 48, 365-388.

Dunstan, B., 1919 - A geological note and sections. *In* Walkom, A.B., Mesozoic floras of Queensland, Parts 3 and 4: The floras of the Burrum and Styx River Series. *Geological Survey of Queensland, Publication* 263.

Elliott, L.G., 1993 - Post-Carboniferous tectonic evolution of eastern Australia. *APEA Journal*, 93, 215-236.

Ellis, P.L., 1966 - The Maryborough Basin. *APEA Journal*, 6, 30-36.

Ellis, P.L., 1968 - Geology of the Maryborough 1:250,000 Sheet area. *Geological Survey of Queensland, Report* 26.

Ellis, P.L., 1976 - Maryborough Basin. *In* Leslie, R.B., Evans, H.J. and Knight, C.L., (Editors), Economic geology of Australia and Papua New Guinea, Volume 3, petroleum. *Australasian Institute of Mining and Metallurgy*, 447-450.

Ellis, P.L. and Whitaker, W.G., 1976 - Geology of the Bundaberg 1:250,000 Sheet area. *Geological Survey of Queensland, Report* 90.

Ericson, E.K., 1976 - Capricorn Basin. *In* Leslie, R.B., Evans, H.J. and Knight, C.L., (Editors), Economic geology of Australia and Papua New Guinea, petroleum, *Australasian Institute of Mining and Metallurgy*, 3, 464-473.

Esso Australia Ltd, 1988 - The Gippsland Basin. *In* Petroleum in Australia: the first century. Australian Petroleum Exploration Association, 174-190.

Etheridge, M., McQueen, H. and Lambeck, K., 1991 - The role of intraplate stress in Tertiary (and Mesozoic) deformation of the Australian continent and its margins: a key factor in petroleum trap formation. *Exploration Geophysics*, 22, 123-128.

Ewart, A., Schön, R.W. and Chappell, B.W., 1991 - The Cretaceous silicic volcanic province of eastern Queensland, Australia: a segment of the S.W. Pacific rift related province. Abstracts, Second Hutton Symposium on Granites and Related Rocks, Canberra, September 1991. *Bureau of Mineral Resources, Australia, Record* 1991/25, p. 34.

© Australian Geological Survey Organisation, 1994

Ewart, A., Schön, R.W. and Stephens, C.J., 1990 - Rift-related Cretaceous volcanism along the central Queensland coast. Proceedings (Volume III) of the Pacific Rim Congress 90, *Australasian Institute of Mining and Metallurgy*, 123-129.

Falvey, D.A., 1974 - The development of continental margins in plate tectonic theory. *APEA Journal*, 14(1), 95-106.

Falvey, D.A. and Mutter, J.C., 1981 - Regional plate tectonics and the evolution of Australia's passive continental margins. *BMR Journal of Australian Geology and Geophysics*, 6(1), 1-29.

Feary, D.A., Davies, P.J., Pigram, C.J. and Symonds, P.A., 1991 - Climatic evolution and control on carbonate deposition in northeast Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 89, 341-361.

Finlayson, D.M., Leven, J.H., Wake-Dyster, K.D. and Johnstone, D.W., 1990 - A crustal image under the basins of southern Queensland along the Eromanga-Brisbane Geoscience Transect. *In* Finlayson, D.M. (Editor), The Eromanga-Brisbane Geoscience Transect: a guide to basin development across Phanerozoic Australia in southern Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 232, 153-175.

Foster, C.B. and Harris, W.K., 1981 - Azolla Capricornica sp. nov. First Tertiary record of Azolla Lamarck (Silviniaceae) in Australia. *Transactions of the Royal Society of South Australia*, 105, 195-204.

Gleadow, A.J.W., 1989 - Thermal history of the Clarence-Moreton Basin in eastern Australia from apatite fission track analysis. Abstract, 28th International Geological Congress, Washington D.C. 1989.

Gleadow, A.J.W. and O'Brien, P.E. (in press) - Apatite fission track thermochronology and tectonics in the Clarence-Moreton Basin of eastern Australia. *In* Wells, A.T. and O'Brien, P.E. (Editors), *Australian Geological Survey Organisation, Bulletin.*

Gray, A.R.G., 1990 - A summary of the petroleum potential of the offshore Queensland continental margin. *Queensland Government Mining Journal*, 91, 489-494.

Grimes, K.G., 1982 - Stratigraphic drilling report - GSQ Sandy Cape 1-3R. *Queensland Government Mining Journal*, 83, 224-233.

Grimes, K.G., 1987 - Fraser Island, Queensland. Australia 1:250 000 Geological Series, Sheet SG 56-3 (part). *Department of Mines, Queensland.*

Grimes, K.G., 1992 - Shallow stratigraphic drilling in the Wide Bay and Maryborough 1:250 000 Sheet areas. *Queensland Resource Industries Record* 1991/30.

Grimes, K.G., Searle, D.E. and Palmieri, V., 1984 - The geological setting of the Capricornia section, Great Barrier Reef Marine Park. *In* Ward, W.T. and Saenger, P. (Editors), The Capricornia section of the Great Barrier Reef - past, present and future, *Royal Society of Queensland Symposium*, 5- 16.

Gulf Research and Development Co. and Australian Gulf Oil Co., 1974 - Marine geophysical reconnaissance of Permits Q/4P, Q/5P, Q/6P, Q/7P and adjacent areas. *PSLA Report* (unpublished).

Haq, B.U., Hardenbol, J. and Vail, P.R., 1988 - Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. *In* Wilgus, C.K., Posamentier, H., Ross, C.A. and Kendall, C.G.St.C. (Editors), Sea-level changes: an integrated approach, *Society of Economic Paleontologists and Mineralogists, Special Publication* 42, 71-108.

Harrington, H.J. and Korsch, R.J., 1985 - Late Permian to Cainozoic tectonics of the New England Orogen. *Australian Journal of Earth Sciences*, 32, 181-203.

Hawthorne, W.L., 1960 - The Burrum Coalfield. *Geological Survey of Queensland, Publication* 296.

© Australian Geological Survey Organisation, 1994

Hayes, D.E. and Ringis, J., 1973 - Sea floor spreading in the Tasman Sea. *Nature*, 242, 454-458.

Hekel, H., 1973 - Late Oligocene to Recent nannoplankton from the Capricorn Basin. *Geological Survey of Queensland, Publication* 359.

Henstridge, D.A. and Missen, D., 1982 - Geology of oil-shale deposits within the Narrows Graben, Queensland, Australia. *American Association of Petroleum Geologists, Bulletin* 66, 719-731.

Hill, P.J. and Pigram, C.J., 1990 - RV *Rig Seismic* investigation of the offshore Maryborough Basin, southern Queensland continental margin and northern Tasman Basin - structure, stratigraphy and petroleum resource potential. *Bureau of Mineral Resources, Australia, Record* 1990/69.

Humber (Barrier Reef Oils Pty Ltd), 1960 - H.B.R. Wreck Island No. 1, Queensland, well completion report. *Bureau of Mineral Resources, Australia, PSSA Publication* 4.

Johnson, R.W., Sun, S.-S. and Wellman, P. 1989 - Problems, uncertainties, and issues. *In* Johnson, R.W., (Editor), Intraplate volcanism in eastern Australia and New Zealand, *Cambridge University Press*, 347-354.

Jones, J.G. and Veevers, J.J., 1983 - Mesozoic origins and antecdents of Australia's Eastern Highlands. *Journal of the Geological Society of Australia*, 30, 305-322.

Keiraville Konsultants Pty Ltd, 1984 - ATP 229 vitrinite reflectance results sheets (for Phoenix Oil and Gas N.L.). Unpublished report held by the Queensland Department of Resource Industries as CR 13647.

Kennett, J.P., von der Borch, C.C. et al., 1985 - Initial Reports of the Deep Sea Drilling Project, Volume 90. *U.S. Government Printing Office, Washington.*

Korsch, R.J., O'Brien, P.E., Harrington, H.J., Wake-Dyster, K.D., Finlayson, D.M. and Johnstone, D.W., 1990 - Constraints from deep seismic profiling on models for the evolution of Permian-Mesozoic sedimentary basins in eastern Australia. *In* Pinet, B. and Bois, C. (Editors), The potential of deep seismic profiling for hydrocarbon exploration, *Éditions Technip*, Paris, 275-290.

Korsch, R.J., O'Brien, P.E., Sexton, M.J., Wake-Dyster, K.D. and Wells, A.T., 1989 - Development of Mesozoic transtensional basins in easternmost Australia. *Australian Journal of Earth Sciences*, 36, 13-28.

Kroenke, L.W., 1984 - Cenozoic tectonic development of the Southwest Pacific. *CCOP/SOPAC Technical Bulletin* 6.

Lambeck, K., 1983 - The role of compressive forces in intracratonic basin formation and mid-plate orogenies. *Geophysical Research Letters*, 10, 845-848.

Lister, G.S., Etheridge, M.A. and Symonds, P.A., 1986 - Detachment faulting and the evolution of passive continental margins. *Geology*, 14, 246-250.

Lister, G.S. and Etheridge, M.A., 1989 - Detachment models for uplift and volcanism in the Eastern Highlands and their application to the origin of passive margin mountains. *In* Johnson, R.W., (Editor), Intraplate volcanism in eastern Australia and New Zealand, *Cambridge University Press*, 297-313.

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

McDougall, I. and Duncan, R.A., 1988 - Age progressive volcanism in the Tasmantid Seamounts. *Earth and Planetary Science Letters*, 89, 207-220.

McIver, R.G., Coshell, L. and Lindner, A.W., 1992 - A tectonic model for Queensland's Teriary oil shale deposits. AAPG International Conference and Exhibition, Sydney, 1992 (Abstracts), 63.

© Australian Geological Survey Organisation, 1994

Marshall, J.F., 1972 - Morphology of the east Australian continental margin between 21°S and 33°S. *Bureau of Mineral Resources, Australia, Record* 1972/70.

Marshall, J.F., 1977 - Marine geology of the Capricorn Channel area. *Bureau of Mineral Resources, Australia, Bulletin* 163.

Marshall, J.F., 1978 - Morphology and shallow structure of the continental shelf of southern Queensland and northern New South Wales. *Bureau of Mineral Resources, Australia, Record* 1978/100.

Marshall, J.F., 1980 - Continental shelf sediments: southern Queensland and northern New South Wales. *Bureau of Mineral Resources, Australia, Bulletin* 207.

Moore, M.E., Gleadow, A.J.W. and Lovering, J.F., 1986 - Thermal evolution of rifted continental margins: new evidence from fission tracks in basement apatites from southeastern Australia. *Earth and Planetary Science Letters*, 78, 255-270.

Murphy, P.R., Schwartzbock, H., Cranfield, L.C., Withnall, I.W. and Murray, C.G., 1976 - Geology of the Gympie 1:250,000 Sheet area. *Geological Survey of Queensland, Report* 96.

Murray, C.G., 1977 - Geological framework of southeast Queensland. In Day, R.W., (Editor), 1977 field conference: Lady Elliott Island - Fraser Island - Gayndah - Biggenden. Geological Society of Australia Inc., Queensland Division, 4-13.

Mutter, J.C., 1974 - Geophysical results from the Coral Sea: continental margins survey report. *Bureau of Mineral Resources, Australia, Record* 1974/116.

Namco Geophysical Co., 1968 - Final report on the north Bundaberg seismic survey A.T.P. 70P, Queensland (for Exoil No Liability) (unpublished).

Noon, T.A. 1984 - Review of oil shale in Queensland. *Geological Survey of Queensland, Record* 1984/56.

Nunn, R.H., 1982 - SONNE SO-15 cruise 1980 off the east coast of Australia, seismic results - Fraser Island. *Geologisches Jahrbuch* D56, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover. 105-110.

O'Brien, P.E., Korsch, R.J., Wells, A.T., Sexton, M.J. and Wake-Dyster, K.D., (in press) - Structure and tectonics of the Clarence-Moreton Basin. *In* Wells, A.T. and O'Brien, P.E. (Editors), *Australian Geological Survey Organisation, Bulletin.*

Palmieri, V., 1984 - Neogene foraminiferida from GSQ Sandy Cape 1-3R bore, Queensland: a biostratigraphic appraisal. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 46, 165-183.

Paris, J-P., 1981 - Géologie de la Nouvelle-Calédonie: un essai de synthèse. *Bureau de Recherches Géologiques et Minières, Mémoire* 113.

Petroleum Resources Assessment And Development Subprogram, 1990 - Petroleum resources of Queensland (review to June 30, 1989). *Queensland Resource Industries Review Series*, Department of Resource Industries, Queensland.

Queensland Department of Mines, 1981 - Annual Report of the Under Secretary for Mines 1980, 80-81.

Robertson, A.D.C., 1990 - Rifting, transfer faulting, and resultant Cainozoic volcanism, Maryborough Basin, southeast Queensland. Proceedings (Volume II) of the Pacific Rim Congress 90, *Australasian Institute of Mining and Metallurgy*, 265-270.

Shaw, R.D., 1978 - Seafloor spreading in the Tasman Sea. *Australian Society of Exploration Geophysicists Bulletin*, 9, 75-81.

Shaw, R.D., 1979 - On the evolution of the Tasman Sea and adjacent continental margins. Ph.D thesis, University of Sydney (unpublished), 312 pp.

Shaw, R.D., 1990 - Development of the Tasman Sea and easternmost Australian continental margin - a review. *In* Finlayson, D.M. (Editor), The Eromanga-Brisbane Geoscience

© Australian Geological Survey Organisation, 1994

Transect: a guide to basin development across Phanerozoic Australia in southern Queensland. *Bureau of Mineral Resources, Australia, Bulletin* 232, 53-66.

Shell Development (Australia) Pty Ltd., 1967 - Gregory River No. 1 well, Queensland, well completion report. *PSSA Report* (unpublished).

Shell Development (Australia) Pty Ltd., 1977 - Report on offshore Queensland seismic scientific investigation. *PSLA Report* (unpublished).

Siller, C.W., 1961 - The geology and petroleum prospects of the Maryborough Basin, Queensland. *Australian Oil and Gas Journal*, 8(3), 30-36.

Smith, R., 1965 - Hervey Bay regional seismic survey, Maryborough Basin, Queensland. Authority to Prospect 70P. Shell Development (Australia) Pty Ltd, SDA Report 57, *PSSA Report* (unpublished).

Stackelberg, U. von (Compiler), 1982 - Heavy-mineral exploration of the east Australian shelf, Sonne Cruise SO-15, 1980. *Geologisches Jahrbuch* D56, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

Sutherland, F.L., 1983 - Timing, trace and origin of basaltic migration in eastern Australia. *Nature*, 305, 123-126.

Sutherland, F.L., 1985 - Regional controls in eastern Australian volcanism. *In* Sutherland, F.L., Franklin, B.J. and Waltho, A.E. (Editors), Volcanism in eastern Australia, with case histories from New South Wales. *Publication, Geological Society of Australia, NSW Division*, 1, 13-32.

Sutherland, F.L., 1991 - Cainozoic volcanism, Eastern Australia: a predictive model based on migration over multiple 'hotspot' magma sources. *In* Williams, M.A.J., De Deckker, P. and Kershaw, A.P. (Editors), The Cainozoic in Australia: a re-appraisal of the evidence. *Geological Society of Australia, Special Publication* 18, 15-43.

Swarbrick, C.F.J., 1976 - Oil shale in Queensland. *In* Leslie, R.B., Evans, H.J. and Knight, C.L., (Editors), Economic geology of Australia and Papua New Guinea, petroleum, *Australasian Institute of Mining and Metallurgy*, 3, 519-524.

Symonds, P.A., 1973 - The structure of the north Tasman Sea. *Bureau of Mineral Resources, Australia, Record* 1973/167.

Symonds, P.A., Capon, D., Davies, P.J., Pigram, C.J. and Feary, D.A., 1987 - Structural style of the Townsville Trough and its implications for the development of the Northeast Australian margin. Extended abstract, BMR Symposium 1987, Canberra.

Symonds, P.A. and Davies, P.J., 1988 - Structure, stratigraphy, evolution and regional framework of the Townsville Trough and the Marion Plateau region. *Bureau of Mineral Resources, Australia, Record* 1988/48.

Tiger, B.M., 1969 - Final report, Hervey Bay R-1 Marine seismic survey, Queensland, Exploration Permit Q/13P. Shell Development (Australia) Pty Ltd, SDA Report 99, *PSSA Report* (unpublished).

Veevers, J.J., 1990 - Pacific rim of Australia: the 600 million year partnership of Gondwanaland and the ocean. Proceedings (Volume II) of the Pacific Rim Congress 90, *Australasian Institute of Mining and Metallurgy*, 151-158.

Veevers, J.J., Powell, C.McA. and Roots, S.R., 1991 - Review of seafloor spreading around Australia. I. Synthesis of the patterns of spreading. *Australian Journal of Earth Sciences*, 38, 373-389.

Walley, A.M., 1992 - Cretaceous-Cainozoic palaeogeography of the New Zealand - New Caledonia region. *Bureau of Mineral Resources, Australia, Record* 1992/11.

Walley, A.M. and Ross, M.I., 1991 - Preliminary reconstructions for the Cretaceous to Cainozoic of the New Zealand - New Caledonia region. *Bureau of Mineral Resources, Australia, Record* 1991/12.

© Australian Geological Survey Organisation, 1994

Weissel, J.K. and Hayes, D.E., 1977 - Evolution of the Tasman Sea reappraised. *Earth and Planetary Science Letters*, 36, 77-84.

Wellman, P., 1987 - Eastern Highlands of Australia; their uplift and erosion. *BMR Journal of Australian Geology and Geophysics*, 10, 277-286.

Willcox, J.B., 1981 - Petroleum prospectivity of the Australian marginal plateaus. Energy Resources of the Pacific Region. *AAPG Studies in Geology*, 12, 245-272.

Wilson, T.C., 1967 - Exploration - Great Barrier Reef area. *APEA Journal*, 7, 33-39.

Wood, G.R., 1986 - Late Oligocene to early Miocene palynomorphs from GSQ Sandy Cape 1-3R. *Geological Survey of Queensland, Publication* 387.

© Australian Geological Survey Organisation, 1994

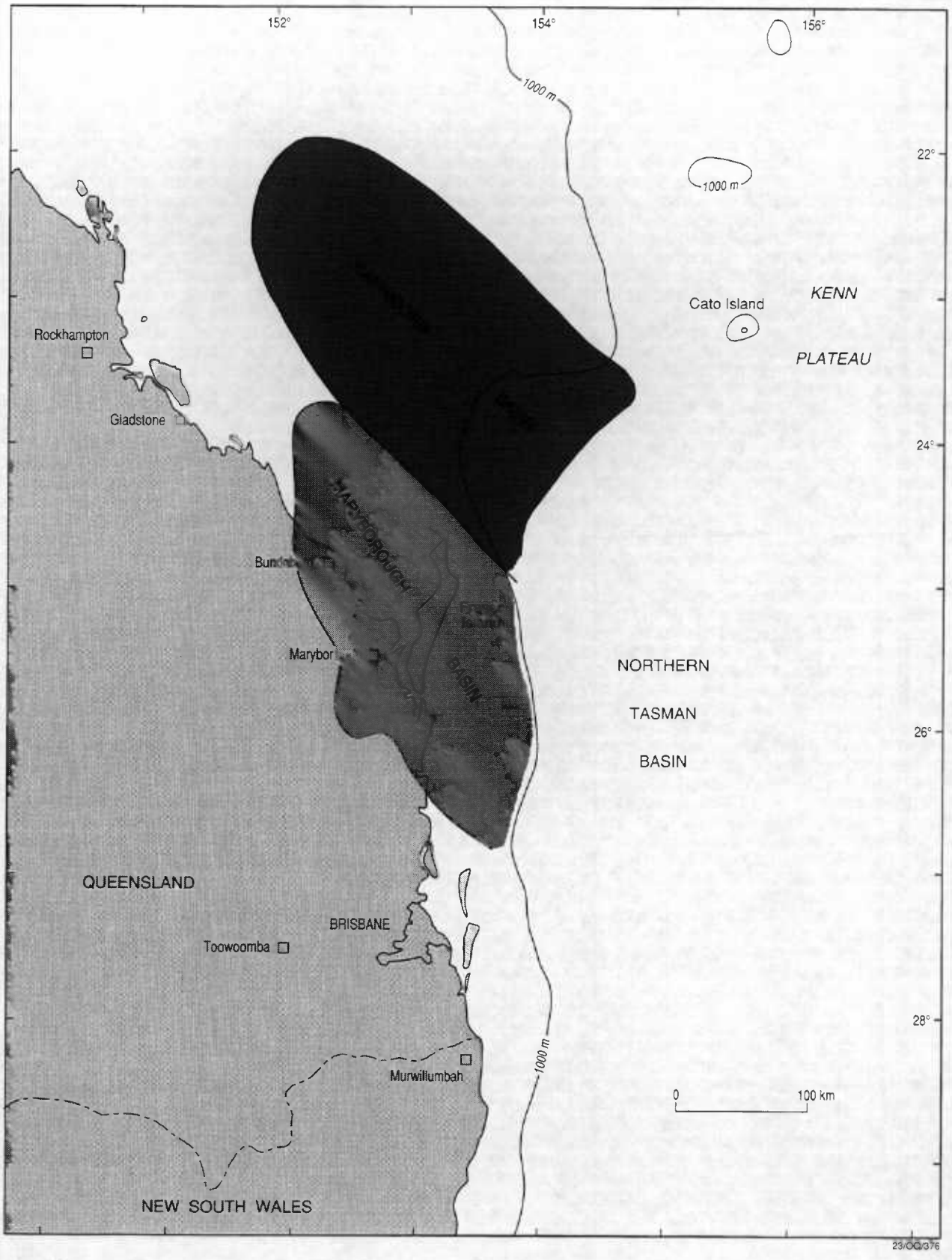


Figure 1. Basin locality map

R9400102

© Australian Geological Survey Organisation, 1994

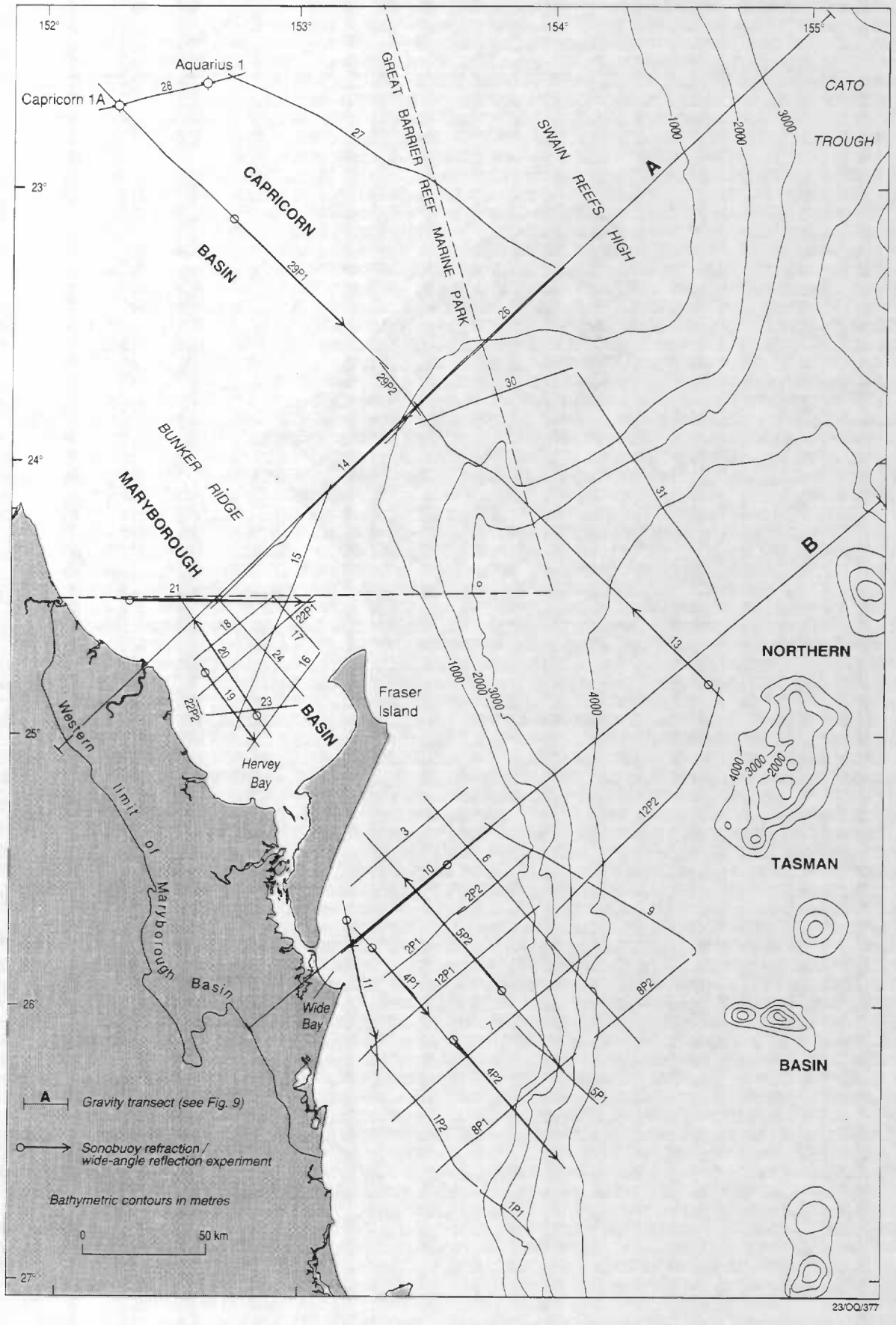


Figure 2. AGSO Survey 91 multichannel seismic reflection lines and sonobuoy experiment locations

© Australian Geological Survey Organisation, 1994

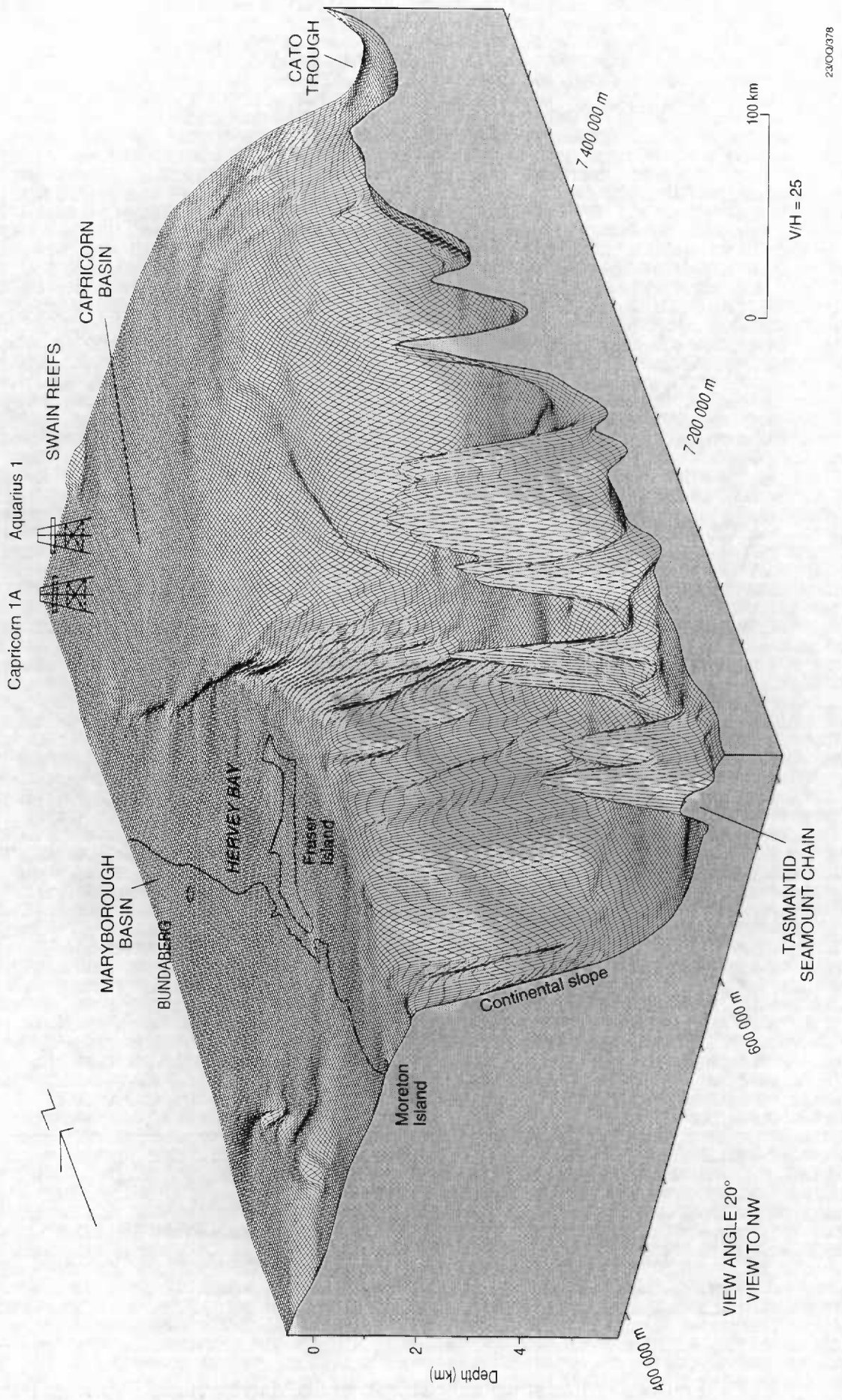


Figure 3. Physiography of the region, 3-D perspective display

© Australian Geological Survey Organisation, 1994

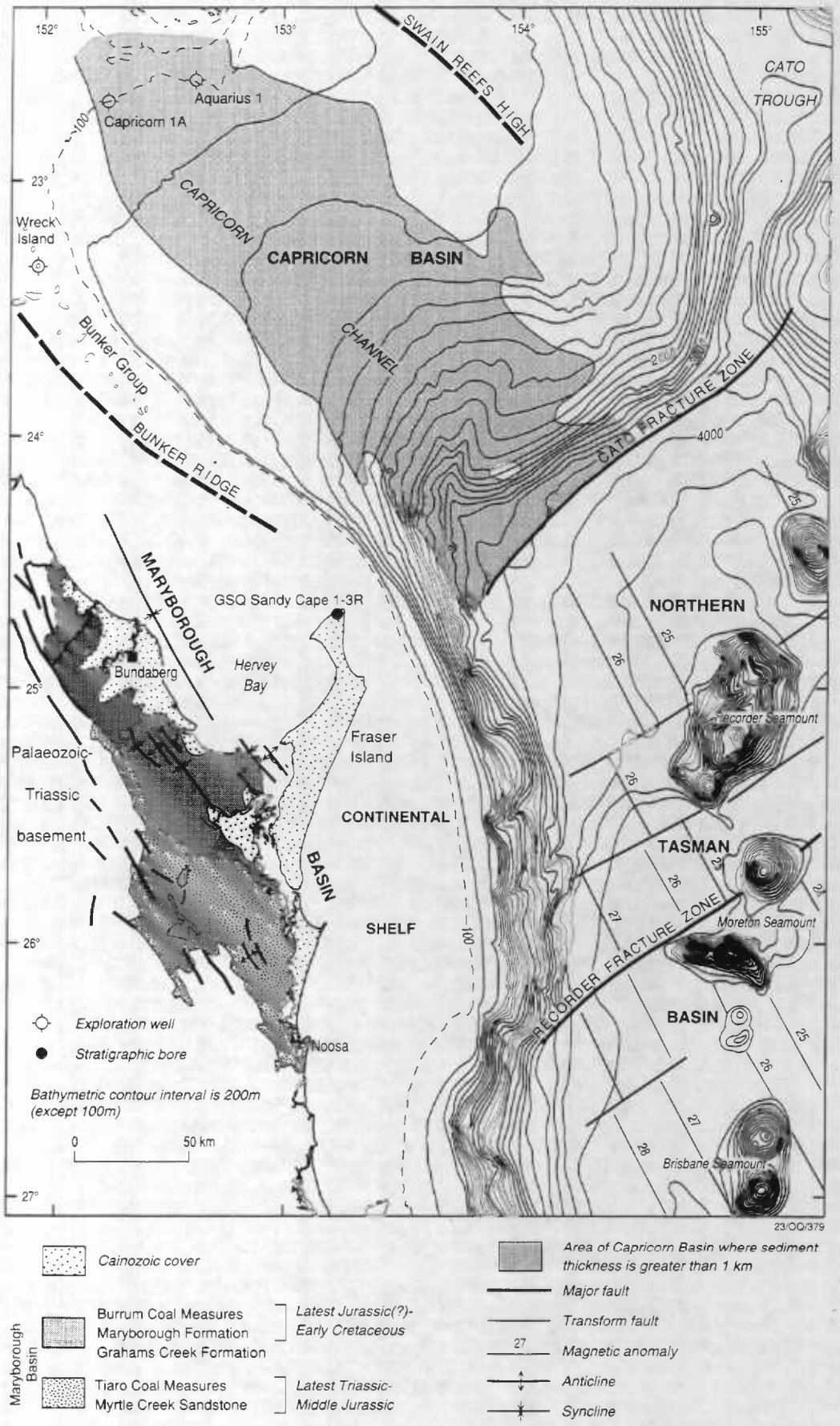


Figure 4. Main structural elements of the Maryborough / Capricorn Basin region

© Australian Geological Survey Organisation, 1994

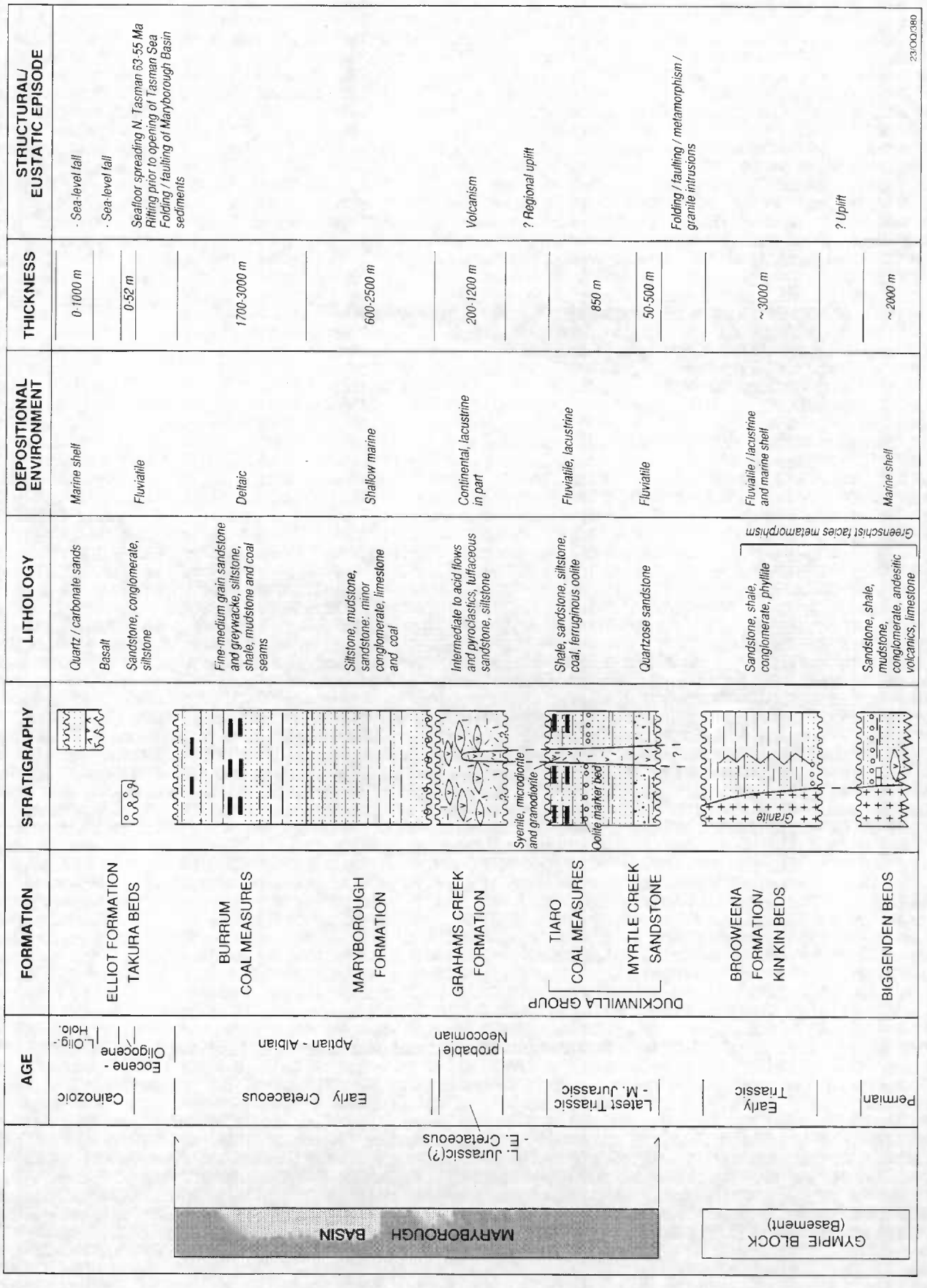


Figure 5. Lithostratigraphic relationships in the Maryborough Basin

© Australian Geological Survey Organisation, 1994

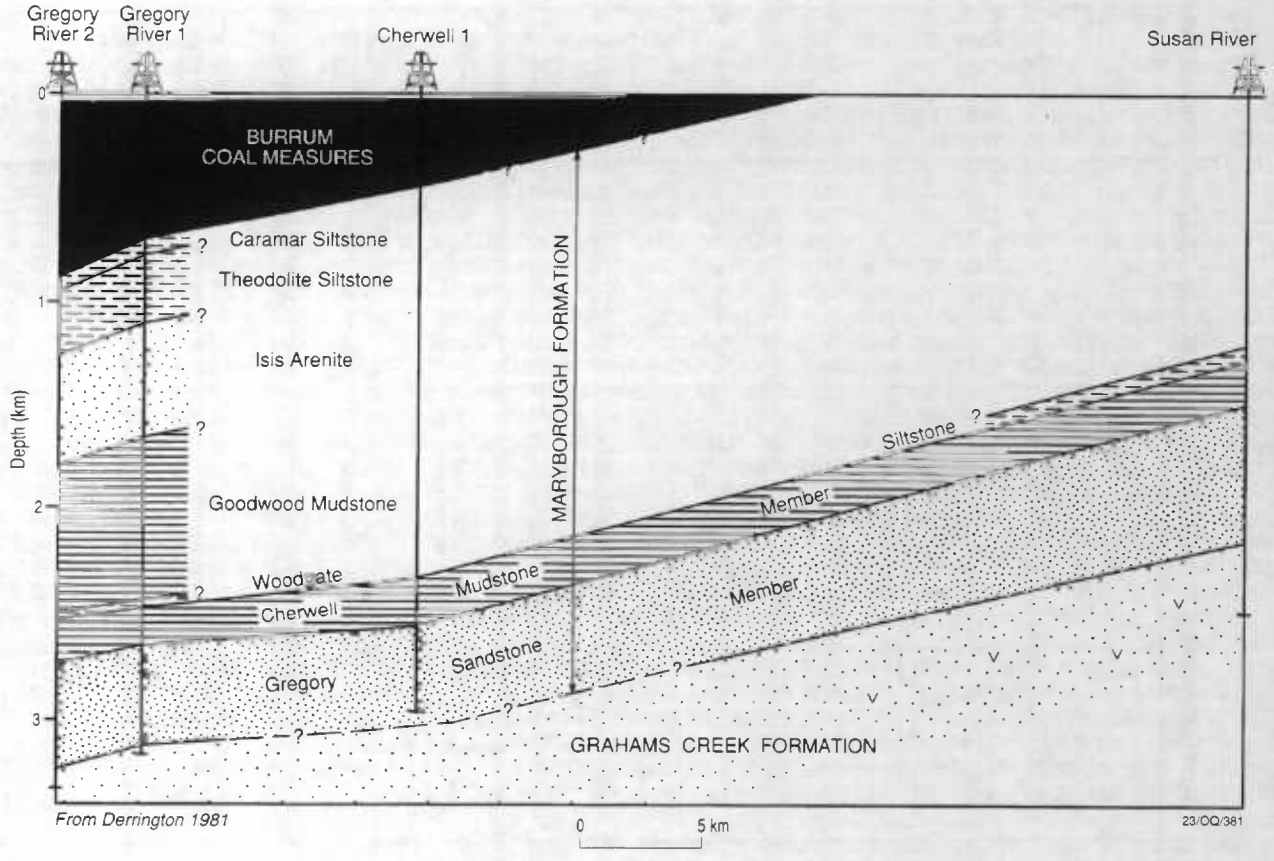


Figure 6. Stratigraphic correlation, Maryborough Basin wells

© Australian Geological Survey Organisation, 1994

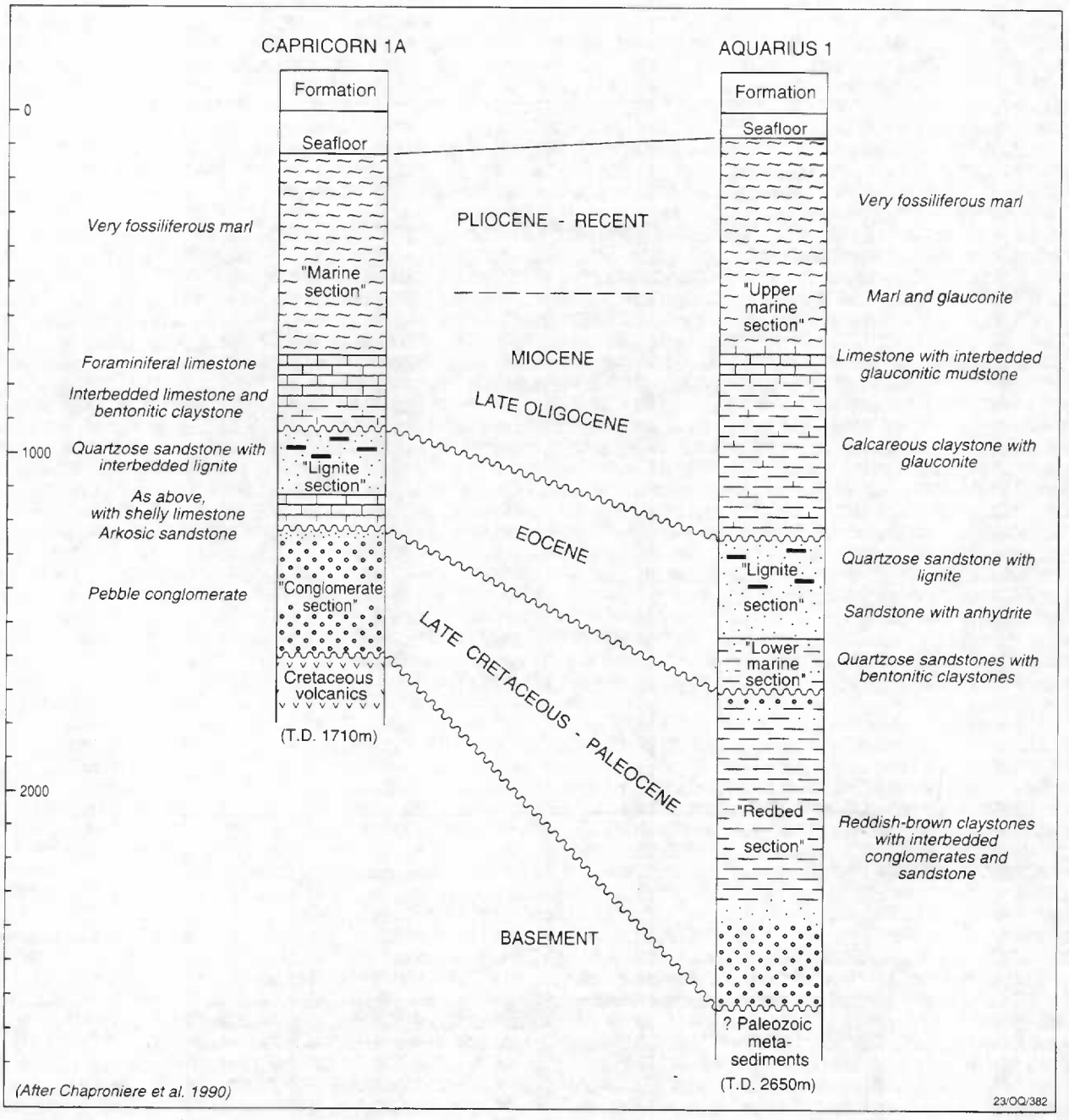


Figure 7. Capricorn-1A and Aquarius-1 geological logs and cross-correlation

© Australian Geological Survey Organisation, 1994

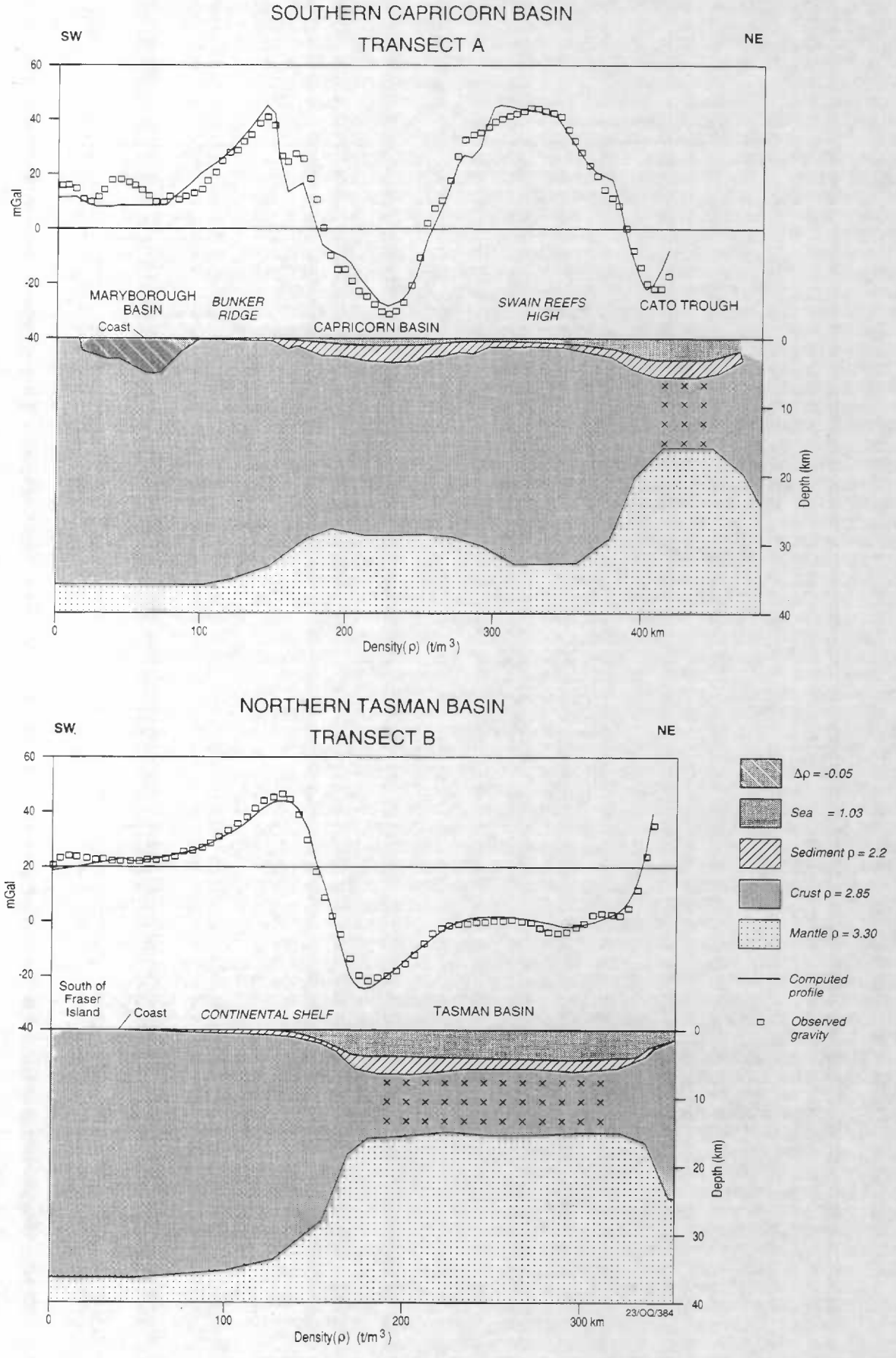


Figure 8. Crustal structure, based on gravity modeling, across the southern Capricorn Basin and across the northern Tasman Basin

© Australian Geological Survey Organisation, 1994

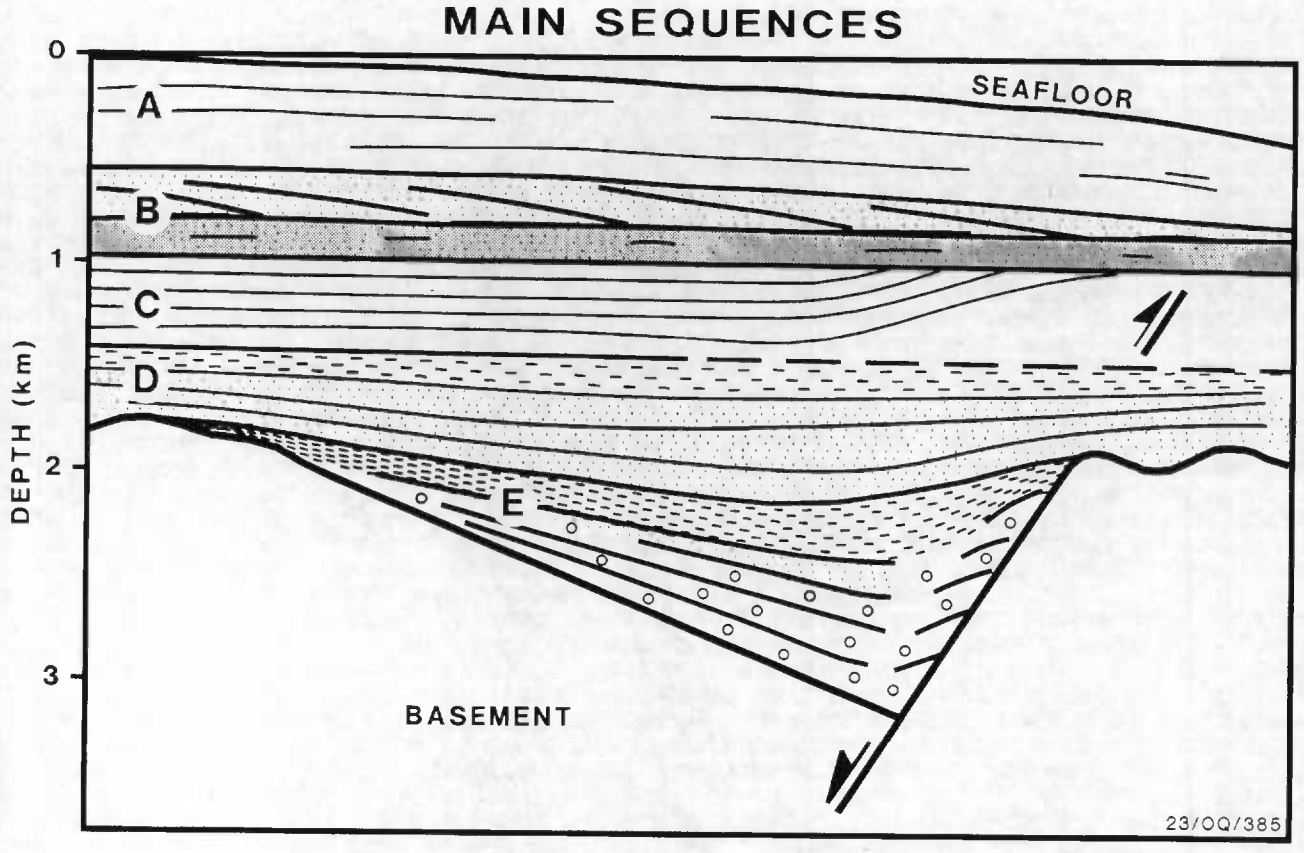


Figure 9. Schematic representation of the main seismic sequences (A-E) in the Capricorn Basin

© Australian Geological Survey Organisation, 1994

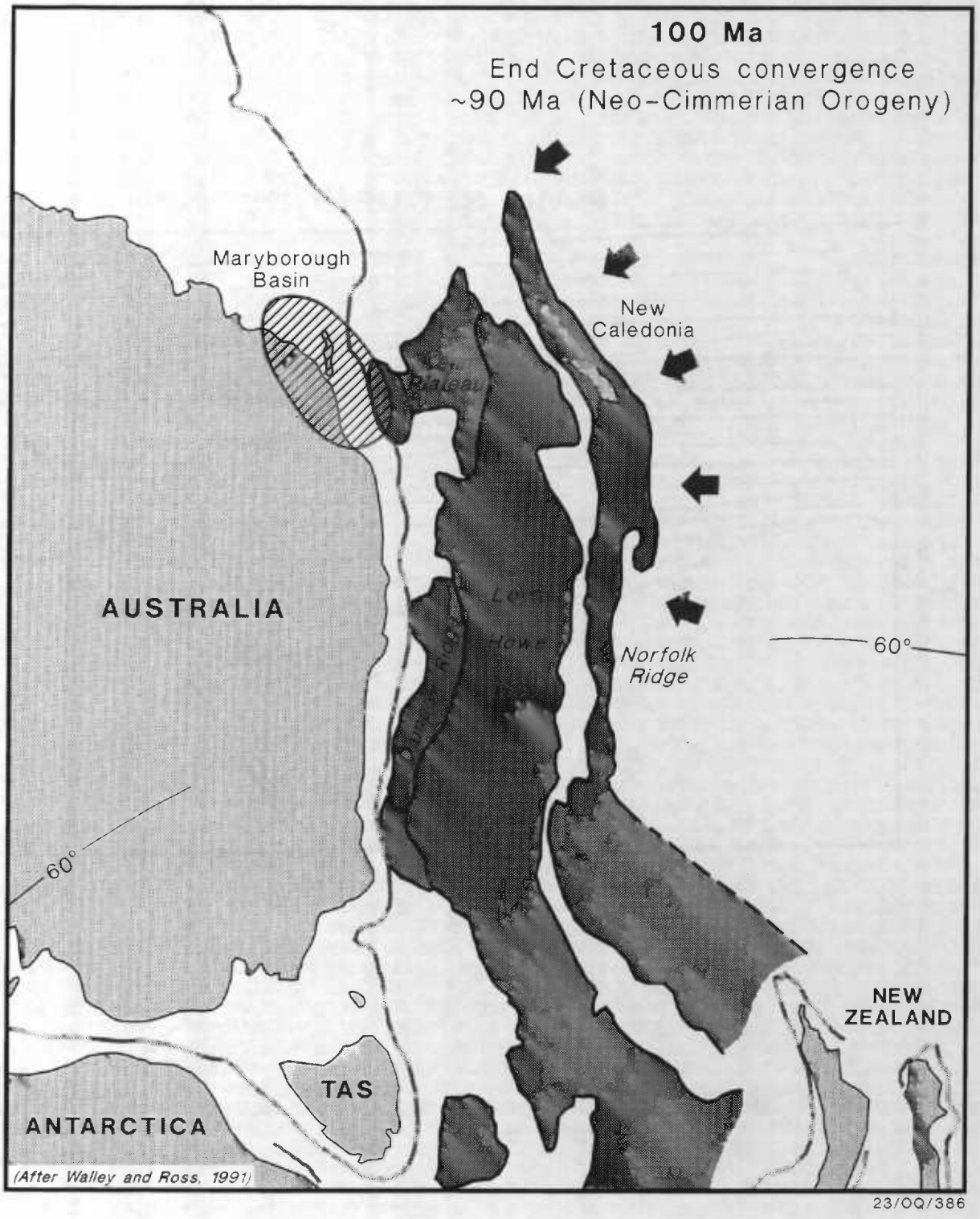


Figure 10. Reconstruction of the eastern margin of the Australian craton at 100 Ma; relationship of the Maryborough Basin to the plate boundary at New Caledonia

© Australian Geological Survey Organisation, 1994

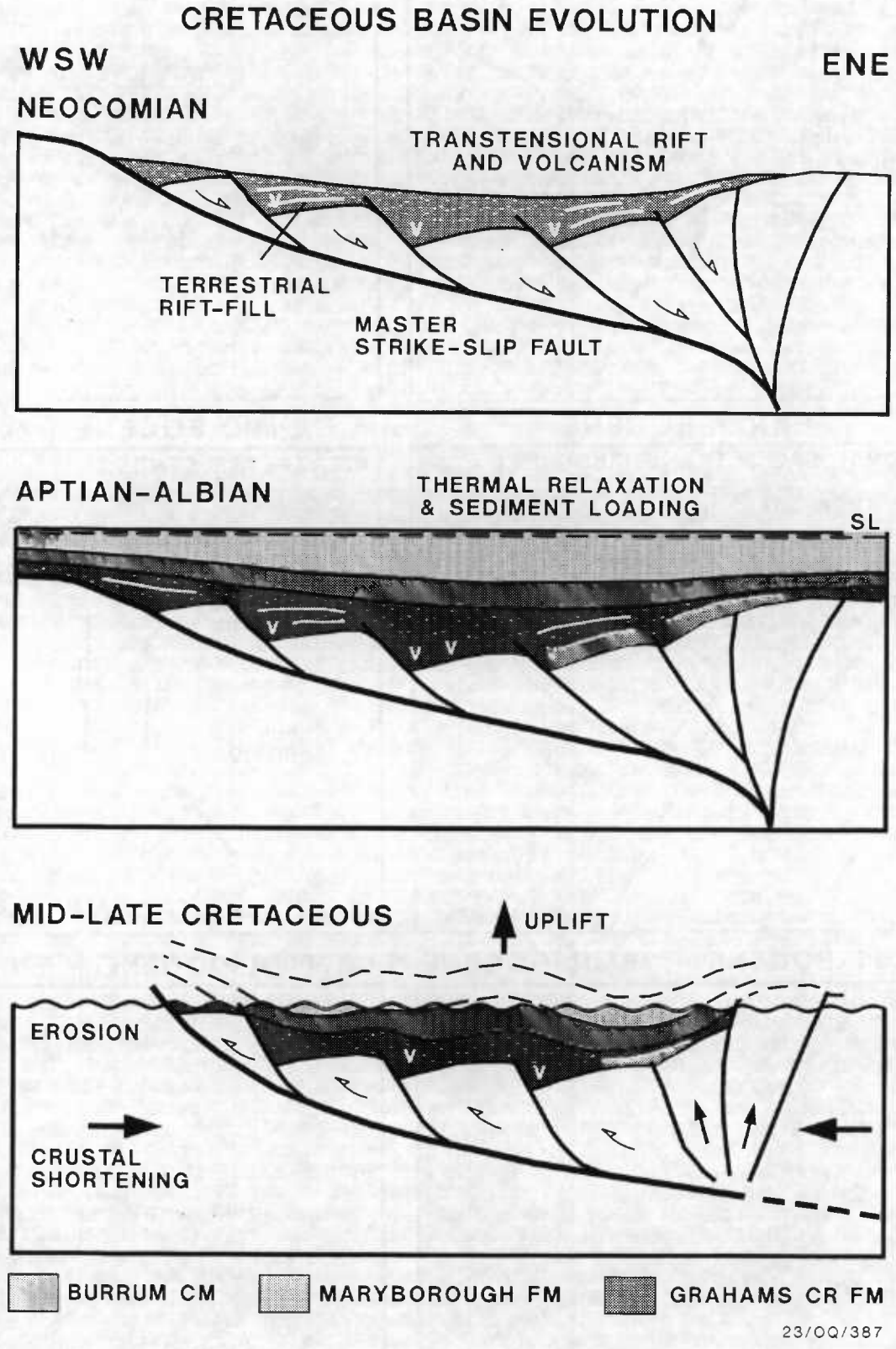


Figure 11. Conceptual evolution of the Maryborough Basin during the Cretaceous

© Australian Geological Survey Organisation, 1994

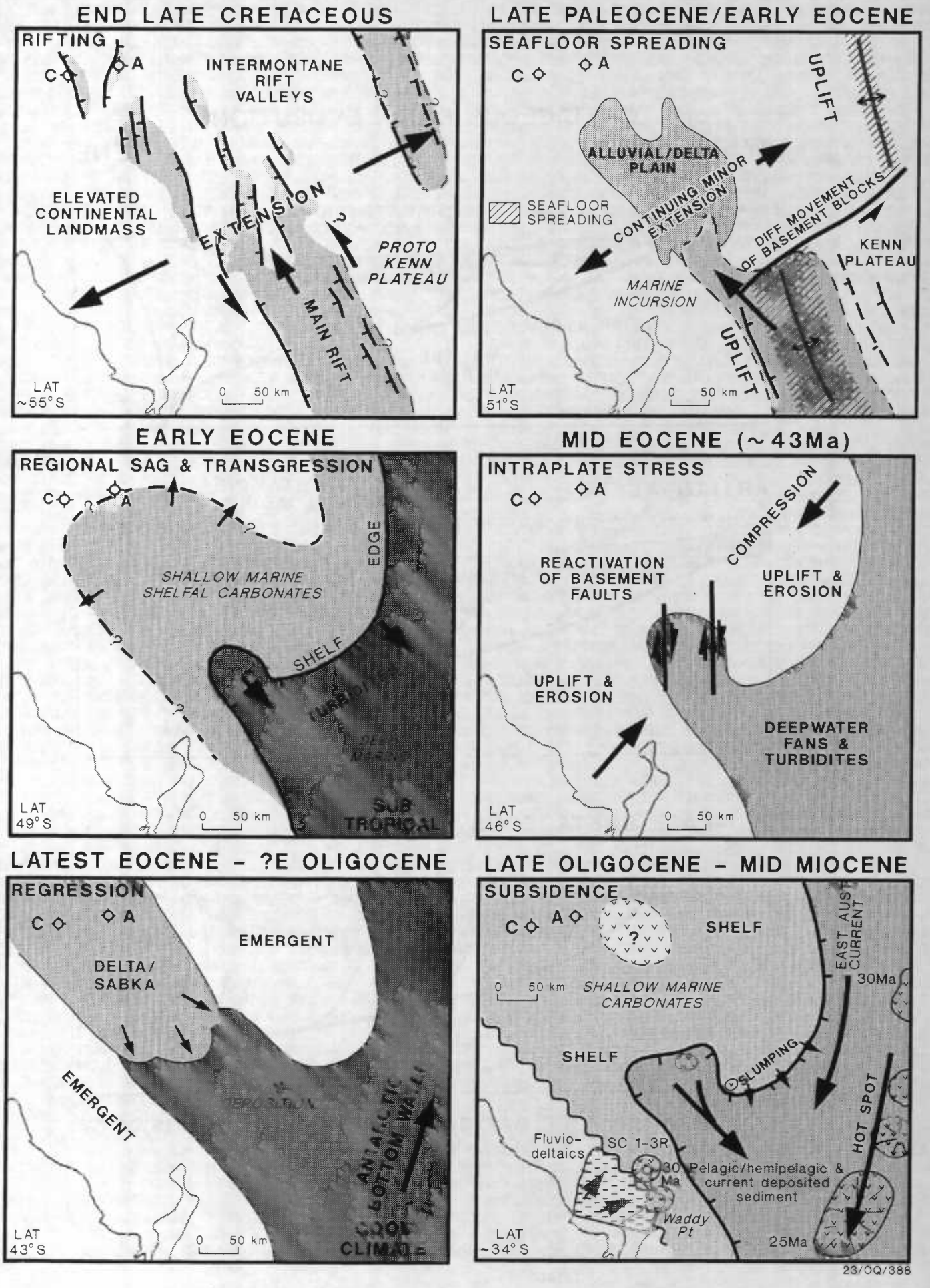


Figure 12. Paleogeographic evolution of the Capricorn / northern Tasman Basins

© Australian Geological Survey Organisation, 1994

TABLE 1
DEEP EXPLORATION WELLS IN THE MARYBOROUGH AND CAPRICORN BASINS

WELL	Cherwell (LSD 1)	Susan River (LSD 2)	Gregory River 1	Capricorn 1A	Aquarius 1	Gregory River 2
BASIN	Maryborough	Maryborough	Maryborough	Capricorn	Capricorn	Maryborough
LATITUDE	25° 14' 43"	25° 21' 10"	25° 08' 20"	22° 42' 14"	22° 37' 13"	25° 06' 30"
LONGITUDE	152° 28' 36"	152° 47' 06"	152° 28' 50"	152° 16' 55"	152° 39' 02"	152° 27' 49"
WATER DEPTH (m)	Onshore	Onshore	Onshore	110	65	Onshore
OPERATOR	Lucky Strike Drilling Co.	Lucky Strike Drilling Co.	Shell Development (Aust.) Pty Ltd	Aust. Gulf Oil Co.	Aust. Gulf Oil Co.	Phoenix Oil & Gas N.L.
SPUD DATE	8 November 1954	9 April 1955	1 November 1966	22 November 1967	21 January 1968	29 April 1981
RIG RELEASE DATE	6 March 1955	9 August 1955	14 February 1967	15 January 1968	27 March 1968	6 July 1981
TD (m)	2979	2459	3160	1710	2650	3310
OLDEST SEQUENCE	?Base Maryborough Formation (Early Cretaceous.)	Grahams Creek Formation (Neocomian)	Grahams Creek Formation (Neocomian)	Cretaceous volcanics, ?Grahams Creek Formation	?Paleozoic shale (slightly metamorphosed)	Grahams Creek Formation (Neocomian)
STATUS	Dry, P&A	Dry, P&A	Gas flows, P&A	Dry, P&A	Dry, P&A	Gas shows, P&A
REFERENCE	Petroleum Resources Assessment and Development Subprogram, 1990; Derrington, 1981	Petroleum Resources Assessment and Development Subprogram, 1990; Derrington, 1981	Shell Development (Aust.) Pty Ltd, 1967	Carlsen and Wilson, 1968a	Carlsen and Wilson, 1968b	Derrington, 1981

R9400103

© Australian Geological Survey Organisation, 1994

TABLE 2
MAIN SEISMIC SEQUENCES, CAPRICORN BASIN

SEQUENCE	AGE	TECTONO-STRATIGRAPHIC UNIT	LITHOLOGY / FACIES	APPROX. THICKNESS (m)
A	Late Oligocene-Recent	Late sag / rapid regional subsidence	Marine carbonates	800
B	mid-Late Eocene	Post tectonic structural reactivation	Deltaic quartz sandstone, lignites, shale; shallow marine sandstone	400
C	Early - Middle Eocene	Early thermal sag phase	Shallow marine; shelf	500
D	Late Paleocene - Early Eocene	Late rift phase	Restricted shallow marine / continental	1000
E	Late Cretaceous - Early Paleocene	Rift phase	Continental - mainly alluvial	2000

© Australian Geological Survey Organisation, 1994

TABLE 3
SONOBUOY RESULTS AND INTERPRETATION, SURVEY 91

LINE 4P1 (time 329.1348)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1470	0	Water column
2000*	50	Late Cainozoic sediments
4200	160	?Maryborough Formation
4680	1760	?Grahams Creek Formation

LINE 4P2 (time 330.0310)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1490	0	Water column
1900*	70	Pliocene-Recent shelfal sediments
2290	205	L.Oligocene-Miocene shallow marine / fluvio-deltaic sediments
4550	700	L. Cretaceous or older section
5350	1380	Basement (?Paleozoic - mid Triassic metamorphics/granite)

LINE 5P2 (time 331.1132)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1560	0	Water column
1900*	70	Pliocene-Recent shallow marine sediments
2180	160	Neogene marine sediments
2850	505	Mid Tertiary sediments/?basalt
5090	1000	Early Cretaceous or older section
5640	4250	Basement (?Paleozoic - mid Triassic metamorphics/granite)

LINE 10 (time 334.2346)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1580	0	Water column
2560	55	Late Cainozoic sediments/?basalt
4370	510	?L. Cretaceous sediments (rift-phase)
4820	1190	?E. Cretaceous or older section
5780	3330	Basement (?Paleozoic - mid Triassic metamorphics/granite)

© Australian Geological Survey Organisation, 1994

LINE 11 (time 335.1155)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1500	0	Water column
2000*	40	Mid-late Cainozoic sediments/?basalt
3950	80	?Burrum Coal Measures (Lower Unproductive)
4310	320	?Maryborough Formation
5550	1430	Grahams Creek Formation

LINE 13 (time 338.0151)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1480	0	Water column
1780	4150	Pliocene-Recent deep marine sediments

LINE 19 (time 341.0128)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1540	0	Water column
2000*	15	Mid-late Cainozoic sediments
3910	110	Burrum Coal Measures (Lower Unproductive)
4300	710	Maryborough Formation
4810	1960	Maryborough Formation (lower)
5130	2500	Grahams Creek Formation
5780	5520	Basement (?Paleozoic - mid Triassic metamorphics/granite)

LINE 20 (time 341.0741)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1530	0	Water column
2000*	20	Mid-late Cainozoic sediments
3950	110	Maryborough Formation
4760	340	Maryborough Formation / ?Grahams Creek Formation
5500	1270	Sub Maryborough Formation section
5700	1980	Basement (?Paleozoic - mid Triassic metamorphics/granite)

© Australian Geological Survey Organisation, 1994

LINE 21 (time 341.2141)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1500	0	Water column
1900*	20	Miocene - Recent marine sediments
2430	140	Mid Tertiary fluvio-deltaics/basalt, weathered Burrum Coal Measures
3020	460	Burrum Coal Measures
4570	2100	Burrum Coal Measures (Lower Unproductive) - Maryborough Formation
5650	4230	Grahams Creek Formation

LINE 29 (time 346.0051)

Velocity of Layer (m/s)	*Depth of Layer (m)*	*Interpretation*
1560	0	Water column
1700*	370	L. Miocene - Recent marl
1940	670	Mid Miocene ?marl
2630	810	Eocene - mid Miocene sediments (marine carbonates / deltaics)
3000	2160	Rift fill deposits, L. Cretaceous - E. Eocene
5150	2910	?Basement (possibly Mesozoic volcanics/conglomerates/indurated sediments
5730	4470	Basement (?Paleozoic - mid Triassic metamorphics/granite

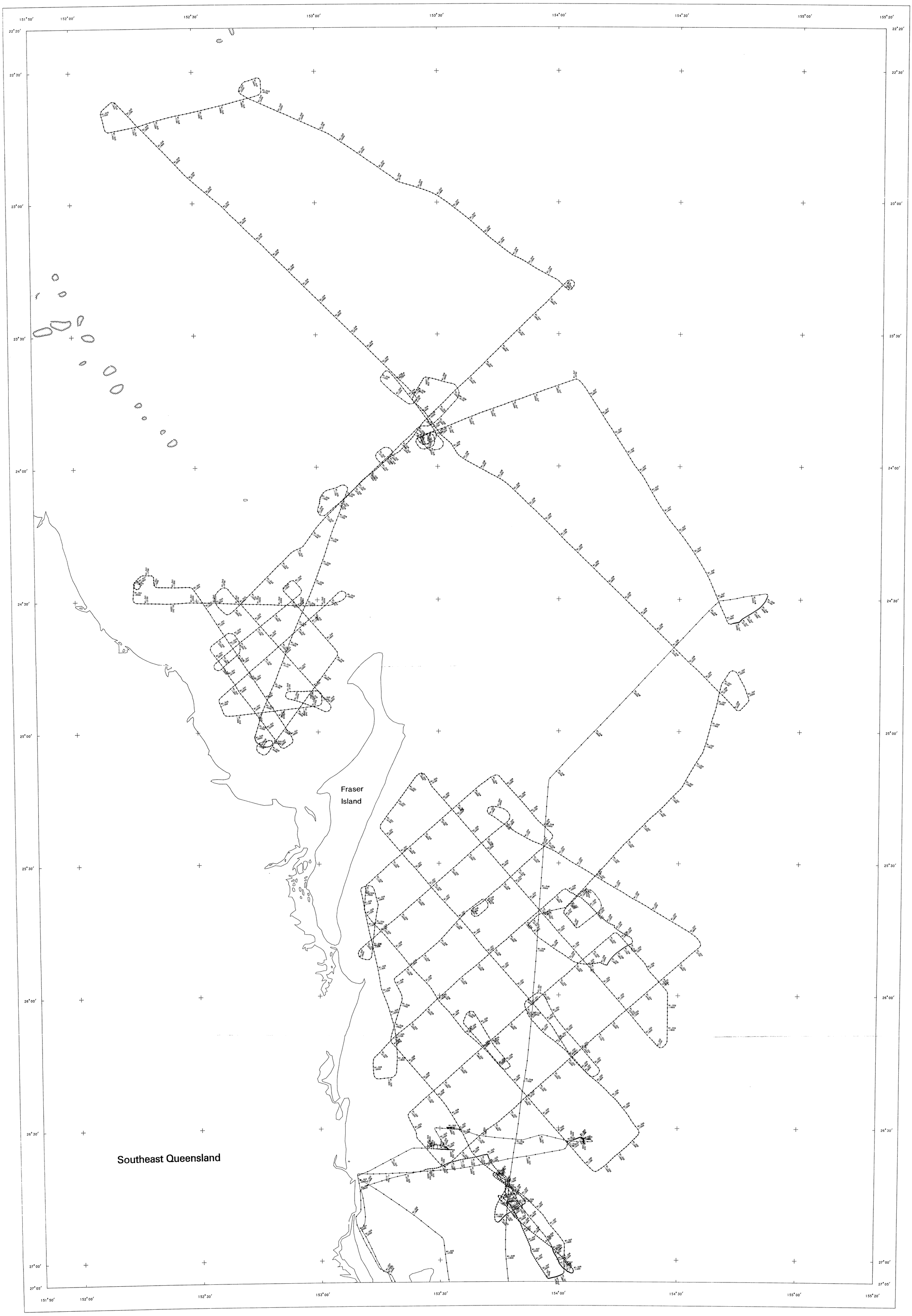
Note: Sonobuoy launch times are in GMT and in the format ddd.hhmm
* denotes assumed velocity

© Australian Geological Survey Organisation, 1994

SURVEY 91 : OFFSHORE SE QUEENSLAND

TIME-ANNOTATED TRACK MAP, RV RIG SEISMIC

SCALE 1:500000



AUSTRALIAN NATIONAL SPHEROID
TRANSVERSE MERCATOR PROJECTION
ZONE 56 - WIDTH OF 6° AND
CENTRAL MERIDIAN 153°00′ EAST

FINAL NAVIGATION

KILOMETRES
10 0 10 20 30 40
5 0 5 10 15 20
NAUTICAL MILES

Survey 91 navigation is based on WGS84 datum

ENCLOSURE 1

SURVEY 91 : OFFSHORE SE QUEENSLAND

TIME-ANNOTATED TRACK MAP, RV RIG SEISMIC

R9400137

OFFSHORE SE QUEENSLAND



091/×××× AGSO SURVEY 91
CMS××× AGSO CONTINENTAL MARGINS SURVEY (1970-73)

S-×× SHELL 1963
M-69×× SHELL 1969
M-70×× SHELL 1970
II×× SHELL 1973-74

65-× GULF 1965
1,2,3,4×× GULF 1966
GP-×,GBR-×× GULF 1973

CS-×× UNITED GEOPHYSICAL 1970

R94001136

SEISMIC LINES AND BATHYMETRY CONTOURS, OFFSHORE SE QUEENSLAND; 1:500 000 SHOT-POINT MAP

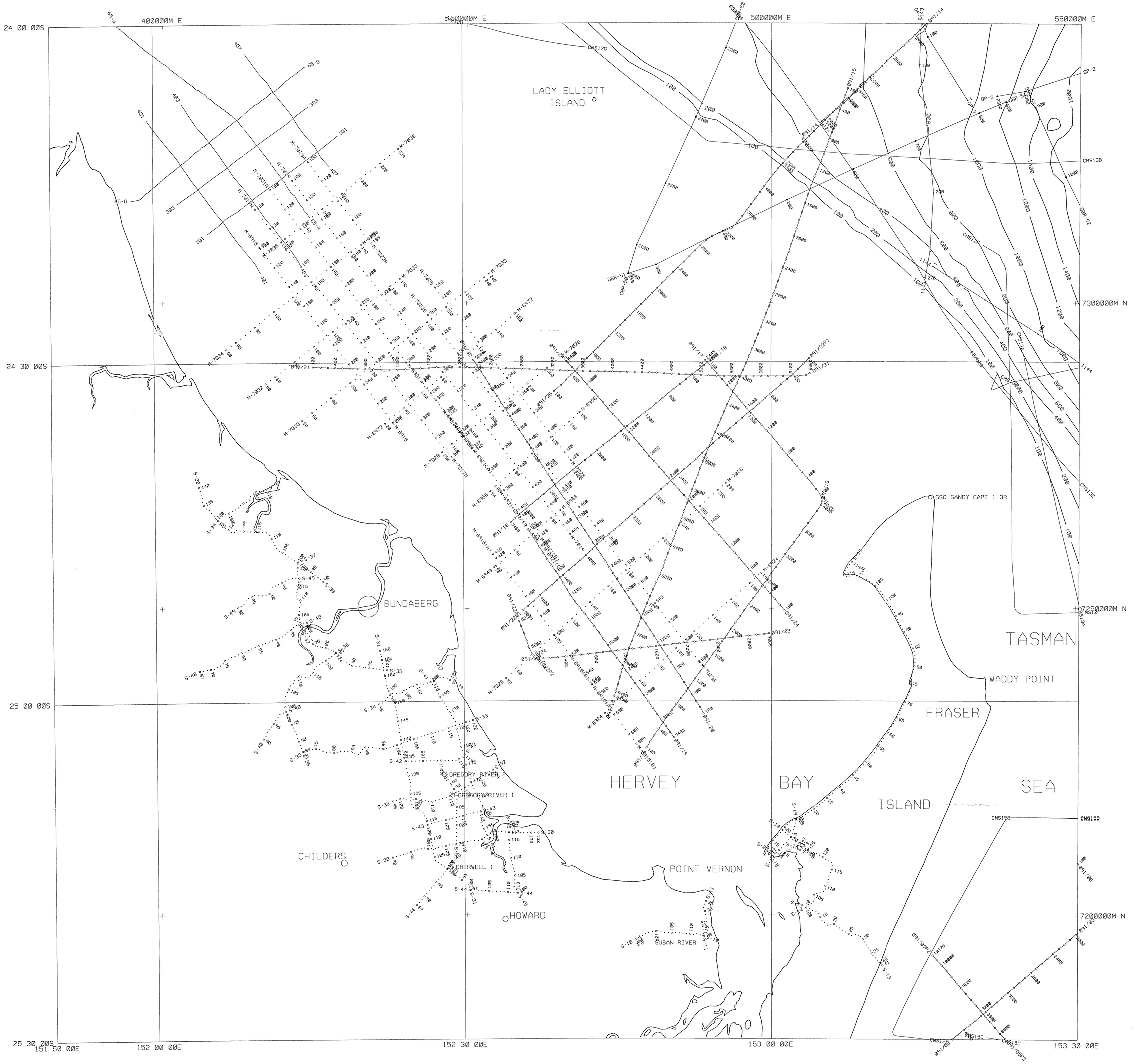
1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

BATHYMETRY: 100M CONTOUR · CONTOURS AT 200M INTERVAL
AGSO SURVEY 91 NAVIGATION IS BASED ON WGS84 DATUM

ENCLOSURE 2

HERVEY BAY AREA



091/×××× AGSO SURVEY 91
CMS/××× AGSO CONTINENTAL MARGINS SURVEY (1970-73)

S-××× SHELL 1963
M-69×× SHELL 1969
M-70×× SHELL 1970
II×× SHELL 1973-74

65-× GULF 1965
3,4×× GULF 1966
QP-×,GBR-×× GULF 1973

SEISMIC LINES, HERVEY BAY AREA:
1:250 000 SHOT-POINT MAP

BATHYMETRY: 100M CONTOUR + CONTOURS AT 200M INTERVAL

AGSO SURVEY 91 NAVIGATION IS BASED ON WGS84 DATUM

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

MARYBOROUGH BASIN

ENCLOSURE 3

R9400135

MARYBOROUGH BASIN

151 55 00E 152 00 00E 152 30 00E 153 00 00E 153 30 00E 153 50 00E

24 05 00S 24 30 00S 25 00 00S 25 30 00S 26 00 00S 26 30 00S 26 35 00S

Lady Elliott Island

K_b subcrop

K_m subcrop

A

A'

B

B'

X

Y

GSQ SANDY CAPE 1-3R
(Cv / 7 RJd)

Bundaberg

Bulfinch Fault

Electra Fault

Cainozoic cover

Paleozoic-Triassic basement

GREGORY RIVER 2

GREGORY RIVER 1

CHERWELL 1

Cherwell Anticline

Pig Creek Syncline

Burrum Syncline

Mined coal seams

Susan Anticline

SUSAN RIVER

Urangan Synclinorium

Woody Anticlinorium

Point Vernon

Moon Point

Hervey Bay

Maryborough

Great Sandy Strait

Waddy Point

Fraser Island

Quaternary Sand

WB-17 (Km)

WB-12 (Km)

WB-11 (RJd)

WB-7 (Km)

WB-1 (RJd)

WB-5 (RJd)

WB-6 (RJd)

WB-3/4 (? Km)

WB-2 (? Km)

Wide Bay

Tasman Sea

Noosa Head

Quaternary Sand

V/H = 4

X SW — Y NE

Burrum Syncline — Susan Anticline — Urangan Synclinorium — Woody Anticlinorium

Mined coal seams — Susan River — Fraser Island

Depth (km)

Basement (Palaeozoic - Triassic)

Basement

Cainozoic cover

Cainozoic

Cv — Volcanics

Early Cretaceous

Kb — Burrum Coal Measures

Km — Maryborough Formation

Late Jurassic - Early Cretaceous

JKg — Grahams Creek Formation

JKi — Syenite, microdiorite, granodiorite (sub-volcanics)

Latest Triassic - Middle Jurassic

RJd — Myrtle Creek Sandstone / Tiaro Coal Measures (Duckinwilla Group)

Areas of bedrock with velocity greater than 4600 m/s

Anticline

Syncline

Fault

WB-2 (Km) GSQ stratigraphic bore and bedrock geology

-4000- Bedrock (sub-Cainozoic) refraction velocity contours in m/s
Contour interval is 200 m/s

Bathymetry contours in metres

Geology based on :-
Hawthorne (1960)
Ellis (1968)
Ellis & Whitaker (1976)
Murphy & Others (1976)
Queensland Department of Mines (1981)
Grimes (1987)
Grimes (1992)
Cranfield (1992)

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 4

Onshore geology of the Maryborough Basin and offshore refraction velocity data (1:250 000 map)

R9400134

OFFSHORE SE QUEENSLAND

400000M E
500000M E
600000M E
700000M E
7500000M N
7400000M N
7300000M N
7200000M N
7100000M N
22 22 ØØS
23 00 ØØS
24 00 ØØS
25 00 ØØS
26 00 ØØS
27 00 ØØS
27 05 ØØS
151 50 ØØE
152 00 ØØE
153 00 ØØE
154 00 ØØE
155 00 ØØE
155 20 ØØE

AQUARIUS 1
CAPRICORN 1A
WRECK ISLAND 1
GSQ SANDY CAPE 1-3R
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER

CAPRICORN BASIN
MARYBOROUGH BASIN
FRASER ISLAND

GRAVITY ANOMALY CONTOUR MAP
OFFSHORE AND ONSHORE SE
QUEENSLAND (1:500 000)

1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

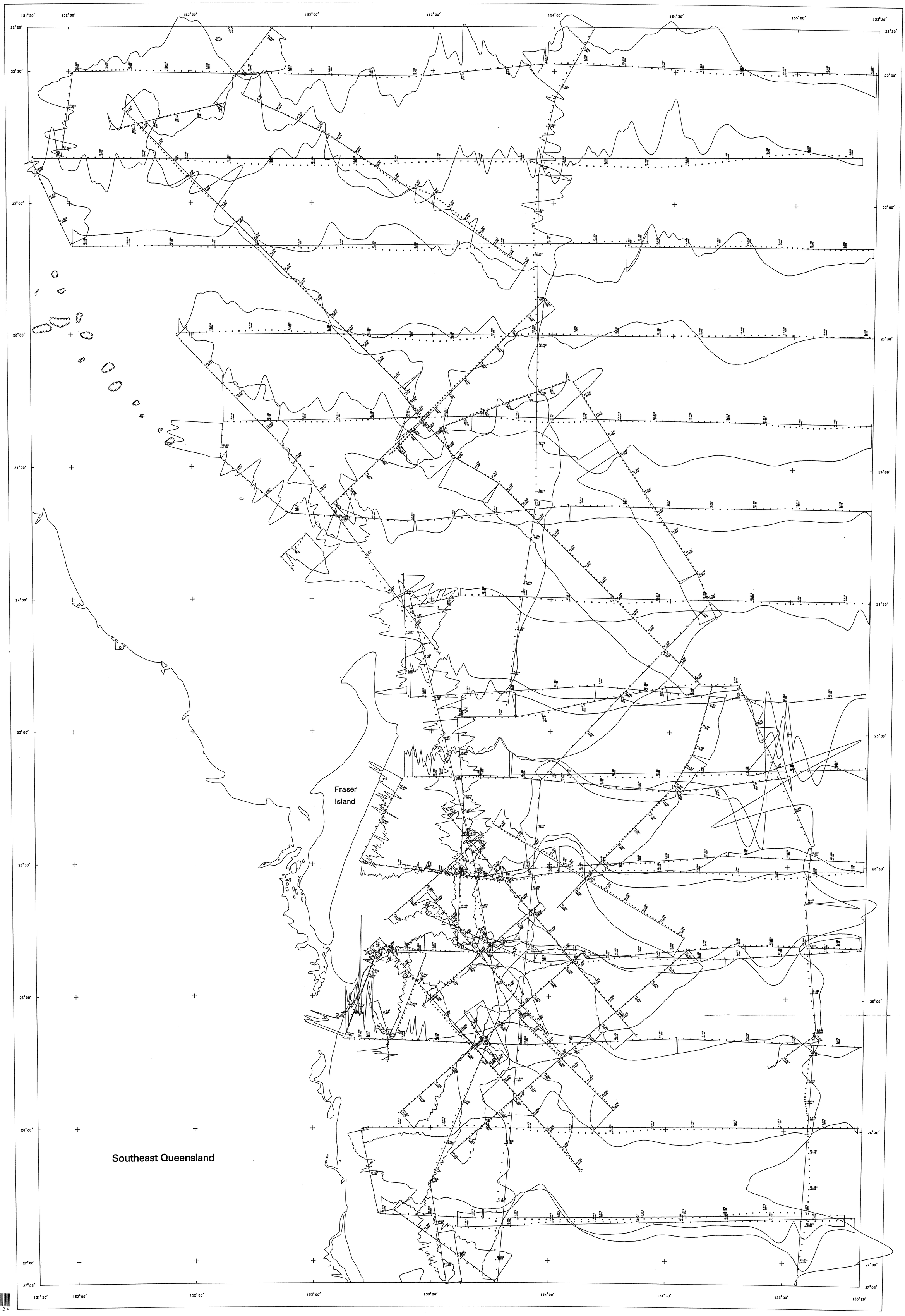
CONTOUR INTERVAL 5MGAL
FREE-AIR ANOMALY OFFSHORE
AREAS LESS THAN +10MGAL SHADED
BOUGUER ANOMALY ONSHORE

R9400133

ENCLOSURE 5

SCALE 1:500000

MAGNETIC PROFILES



TRANSVERSE MERCATOR PROJECTION
ZONE 56 - WIDTH OF 6° AND
CENTRAL MERIDIAN 153°00′ EAST

Profile scale 100nT/cm

Magnetic anomalies based on IGRF80

ENCLOSURE 6

MARYBOROUGH

MAGNETIC PROFILES

R9400132

HERVEY BAY AREA

400000M E
450000M E
500000M E
550000M E
24 00 00S
25 00 00S
25 30 00S
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E
7300000M N
7250000M N
7200000M N

Lady Elliott Island
Bundaberg
Childers
Howard
Point Vernon
Fraser Island
Tasman Sea
Waddy Point
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER
GSQ SANDY CAPE 1-3R

H *Structural high*

L *Structural low*

—250— Two way time contour (contour interval is 50 milliseconds)

Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 7

Time structure map - base Cainozoic section, Hervey Bay area

23/00/390

R94000131

HERVEY BAY AREA

24 00 00S
25 00 00S
25 30 00S
400000M E
450000M E
500000M E
550000M E
7300000M N
7250000M N
7200000M N
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E

Lady Elliott Island
Bundaberg
Childers
Howard
Bullyard Fault Zone
Burrum L Syncline
GREGORY RIVER
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER
Point Vernon
GSQ SANDY CAPE 1-3R
Tasman Sea
Waddy Point
Fraser Island

Fault
Normal fault
Reverse fault
Outcrop/subcrop (beneath Cainozoic) boundary of Burrum Coal Measures - onshore

H *Structural high*
L *Structural low*
-1400- *Two way time contour (contour interval is 100 milliseconds)*
Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 8

Time structure map - horizon A (top Lower Unproductive member of Burrum Coal Measures), Hervey Bay area

23/00/291

R9400130

HERVEY BAY AREA

24 00 00S
25 00 00S
25 30 00S
400000M E
450000M E
500000M E
550000M E
7300000M N
7250000M N
7200000M N
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E

Lady Elliott Island
Bundaberg
Childers
Howard
Fraser Island
Point Vernon
Waddy Point
Tasman Sea
Paleozoic - Triassic Basement
GSQ SANDY CAPE 1-3R
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER

Outcrop / subcrop beneath Cainozoic (onshore)
- Maryborough Formation
- Grahams Creek Formation
- Duckinwilla Group

Fault
Normal fault
Reverse fault

H Structural high
L Structural low
-1000- Two way time contour (contour interval is 100 milliseconds)
Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

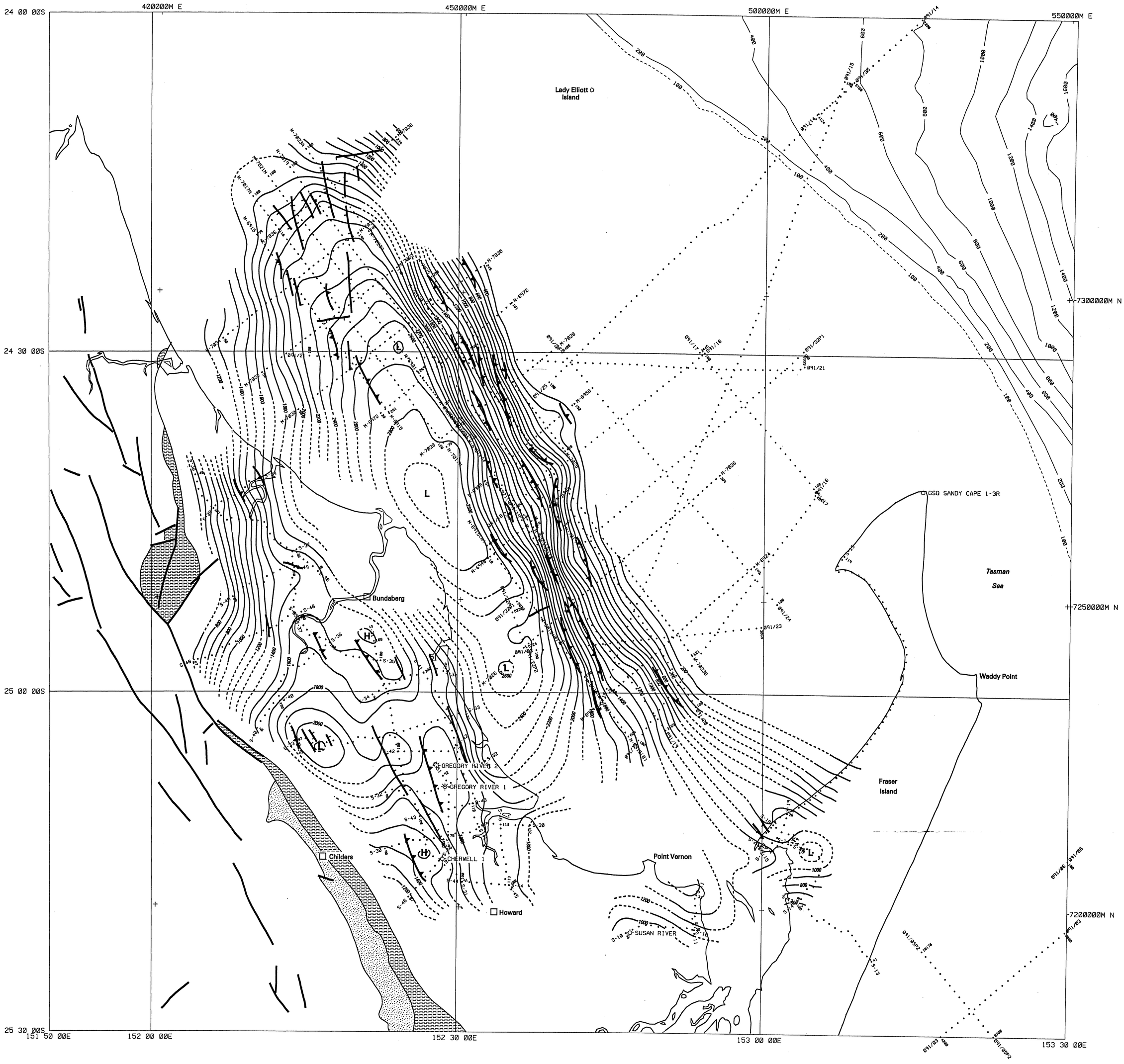
ENCLOSURE 9

Time structure map - horizon A1 (top of Maryborough Formation), Hervey Bay area

R9400129

23/00/302

HERVEY BAY AREA



Outcrop / subcrop beneath Cainozoic (onshore)

- Grahams Creek Formation
- Duckinwilla Group

- *Fault*
- *Normal fault*
- *Reverse fault*

- H *Structural high*
- L *Structural low*
- ~2000~ *Two way time contour (contour interval is 100 milliseconds)*
- *Bathymetry contours in metres*

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 10

Time structure map - horizon B (base of Maryborough Formation), Hervey Bay area

R9400128

HERVEY BAY AREA

400000M E
450000M E
500000M E
550000M E
24 00 00S
24 30 00S
25 00 00S
25 30 00S
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E
7300000M N
7250000M N
7200000M N

Lady Elliott Island
Bundaberg
Childers
Howard
Point Vernon
Fraser Island
Tasman Sea
Waddy Point
GSQ SANDY CAPE 1-3R
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER
L

L *Structural low*

-2000- *Two way time contour (contour interval is 200 milliseconds)*

Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 11

Time structure map - horizon C (base sub Maryborough Formation sequence), Hervey Bay area

R9400127

HERVEY BAY AREA

24 00 00S
24 30 00S
25 00 00S
25 30 00S
400000M E
450000M E
500000M E
550000M E
7300000M N
7250000M N
7200000M N
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E

Lady Elliott Island
Bundaberg
Childers
Howard
Waddy Point
Fraser Island
Point Vernon
Tasman Sea
GSQ SANDY CAPE 1-3R
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER
H

H *Structural high*

*3000 – *Two way time contour (contour interval is 200 milliseconds)*

Bathymetry contours in metres

Datum: sea level

ENCLOSURE 12

Time structure map - "basement" horizon, Hervey Bay area

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

23/OQ/395

R9400126

HERVEY BAY AREA

400000M E
450000M E
500000M E
550000M E
24 00 00S
24 30 00S
25 00 00S
25 30 00S
7300000M N
7250000M N
7200000M N
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E

Lady Elliott Island
Bundaberg
Childers
Howard
Point Vernon
Fraser Island
Waddy Point
Tasman Sea
GSQ SANDY CAPE 1-3R
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER

Areas of thickness greater than 600 milliseconds

Local thickening

Local thinning

-500- Two way time thickness (contour interval is 50 milliseconds)

Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

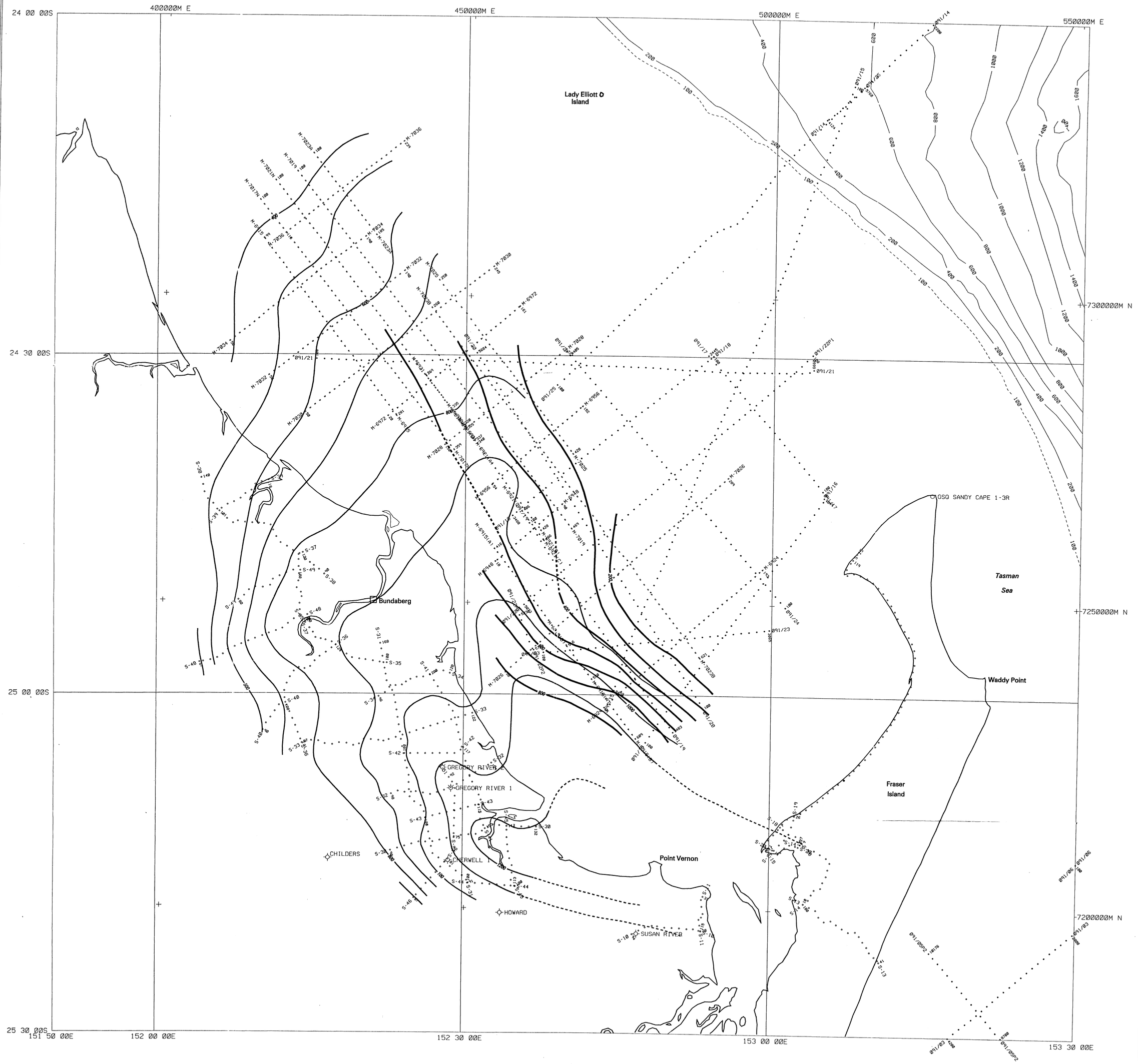
ENCLOSURE 13

Lower L: >productive member of Burrum Coal Measures
(horizon A-A1) time thickness, Hervey Bay area

23/00/396

R9400125

HERVEY BAY AREA



-1000- *Two way time thickness, Maryborough Formation (horizon A1-B)*

=600= *Two way time thickness, sub Maryborough Formation sequence (horizon B-C)*

Contour Interval = 100 milliseconds

Bathymetry contours in metres

1:250000

0 5 10 15 20 25

KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 14

Maryborough Formation (horizon A1-B) time thickness and sub Maryborough Formation sequence (horizon B-C) time thickness, Hervey Bay area

R9400124

HERVEY BAY AREA

400000M E
450000M E
500000M E
550000M E
24 00 00S
24 30 00S
25 00 00S
25 30 00S
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E
7300000M N
7250000M N
7200000M N

Lady Elliott Island
GSQ SANDY CAPE 1-3R
Tasman Sea
Waddy Point
Fraser Island
Point Vernon
Bundaberg
Childers
Howard
GREGORY RIVER 2
GREGORY RIVER 1
CHERWELL 1
SUSAN RIVER

Outcrop / subcrop beneath Cainozoic (onshore)
- Maryborough Formation
- Grahams Creek Formation
- Duckinwilla Group

Fault
Normal fault
Reverse fault

H Structural high
L Structural low
-2800- Depth to horizon A1 in metres (contour interval is 100 metres)
Bathymetry contours in metres

Datum: sea level

ENCLOSURE 15

Structure contour map - horizon A1 (top of Maryborough Formation), Hervey Bay area

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

23/OQ/398

R9400123

HERVEY BAY AREA

24 00 00S
25 00 00S
25 30 00S
400000M E
450000M E
500000M E
550000M E
7300000M N
7250000M N
7200000M N
151 50 00E
152 00 00E
152 30 00E
153 00 00E
153 30 00E

Lady Elliott Island
Bundaberg
Childers
Howard
CHERWELL
GREGORY RIVER
GREGORY RIVER 1
SUSAN RIVER
Point Vernon
Fraser Island
Waddy Point
OGSQ SANDY CAPE 1-3R
Tasman Sea
Paleozoic-Triassic basement

Outcrop / subcrop beneath Cainozoic (onshore)

- Grahams Creek Formation
- Duckinwilla Group

Fault
Normal fault
Reverse fault

H *Structural high*
L *Structural low*
-3000- *Depth to B in metres (contour interval is 100 metres)*
Bathymetry contours in metres

1:250000
0 5 10 15 20 25
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

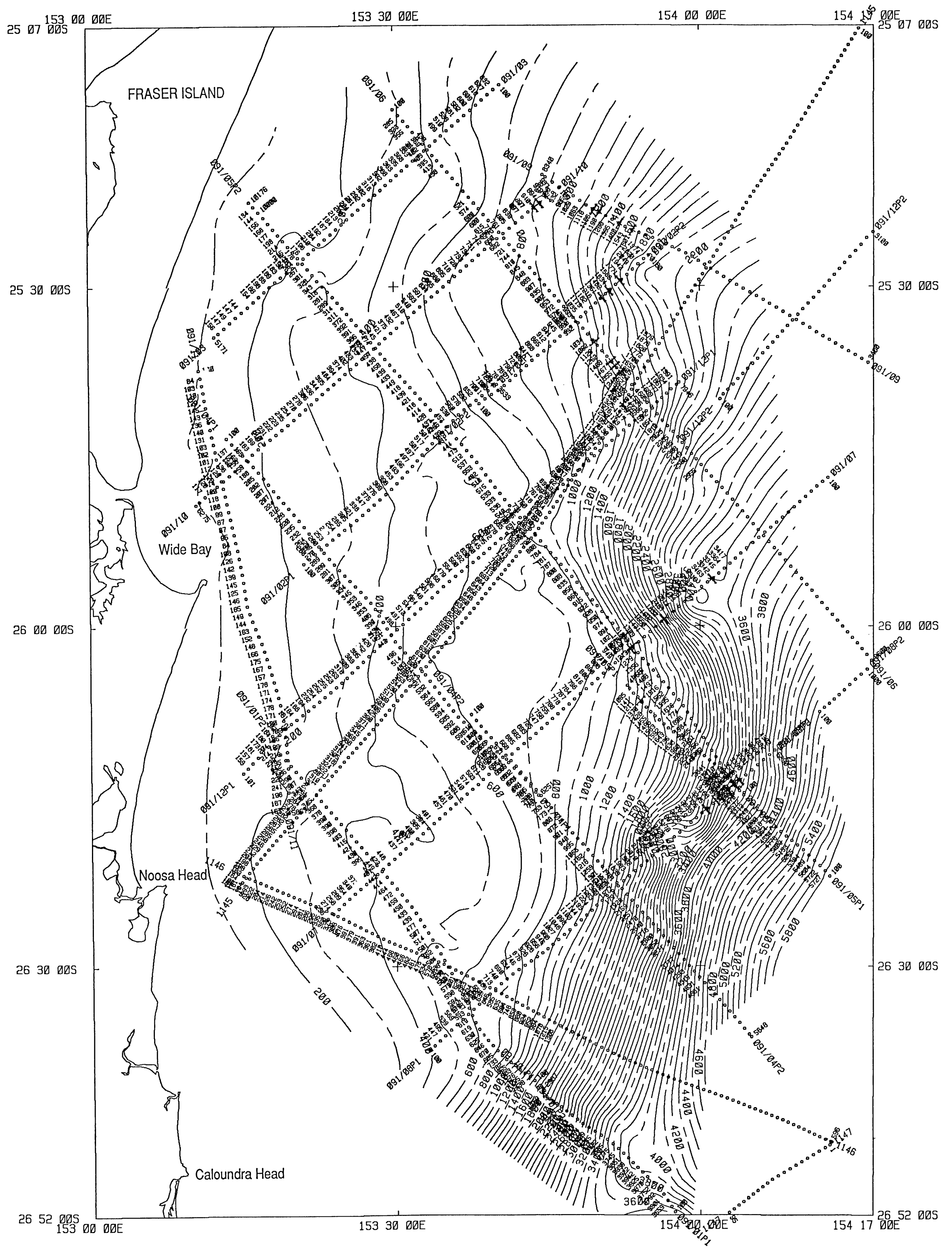
Datum: sea level

ENCLOSURE 16

Structure contour map - horizon B (base of Maryborough Formation), Hervey Bay area

R9400122

SHELF SE OF FRASER ISLAND



Posted and contour values are in milliseconds two-way time.
Contour interval is 100 milliseconds.

1:500000
0 10 20 30 40 50
KILOMETRES

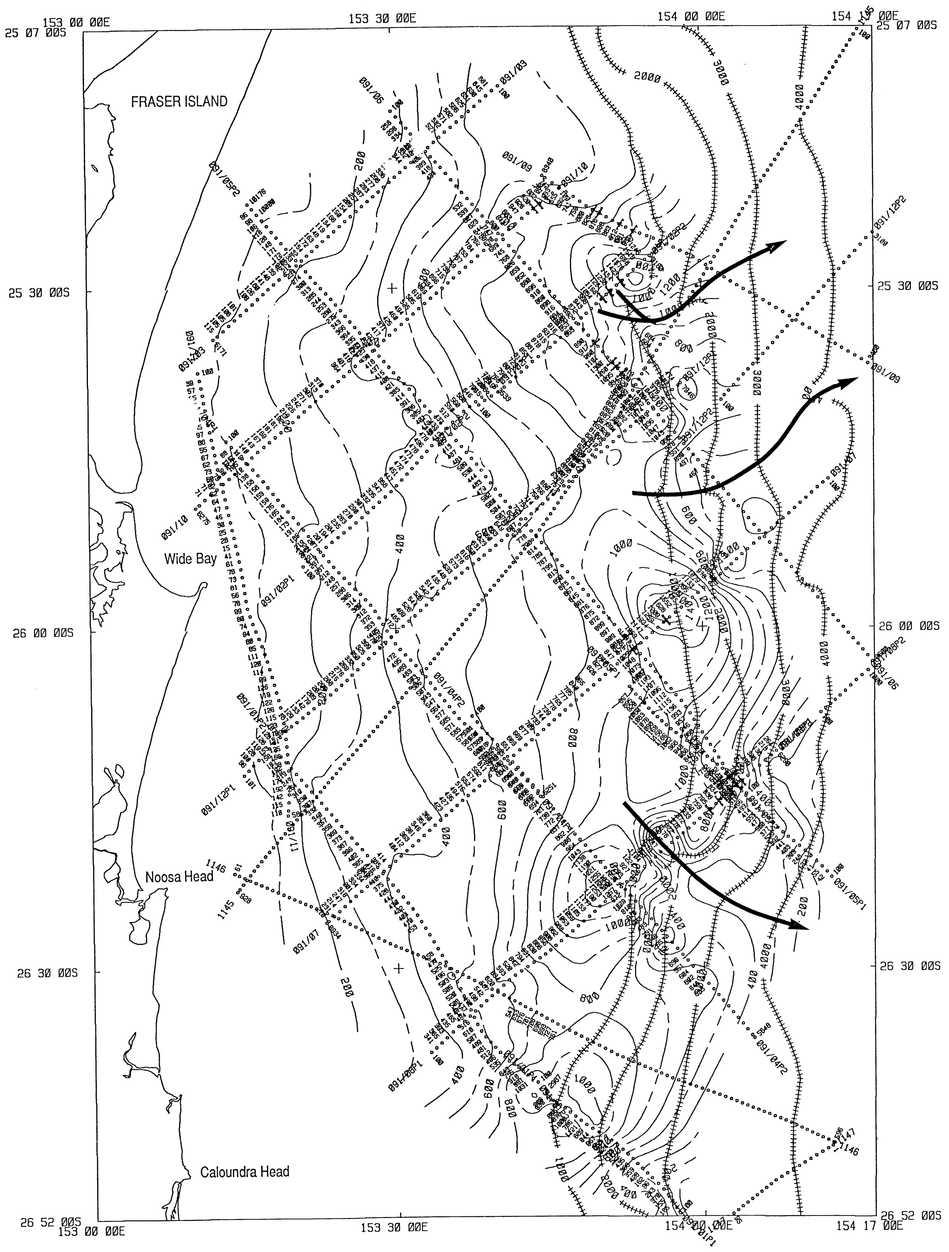
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 17

SHELF SE OF FRASER ISLAND
TIME STRUCTURE MAP
EARLY OLIGOCENE UNCONFORMITY

R9400121

SHELF SE OF FRASER ISLAND



Posted values and isopach contours are in metres.
Isopach contour interval is 100 metres.
Thickness computations are based on interval velocity of 2250 m/s.

Bathymetry contours (hatched) are at 1000 metre interval.

Thick arrowed lines represent canyons.

1:500000
0 10 20 30 40 50
KILOMETRES

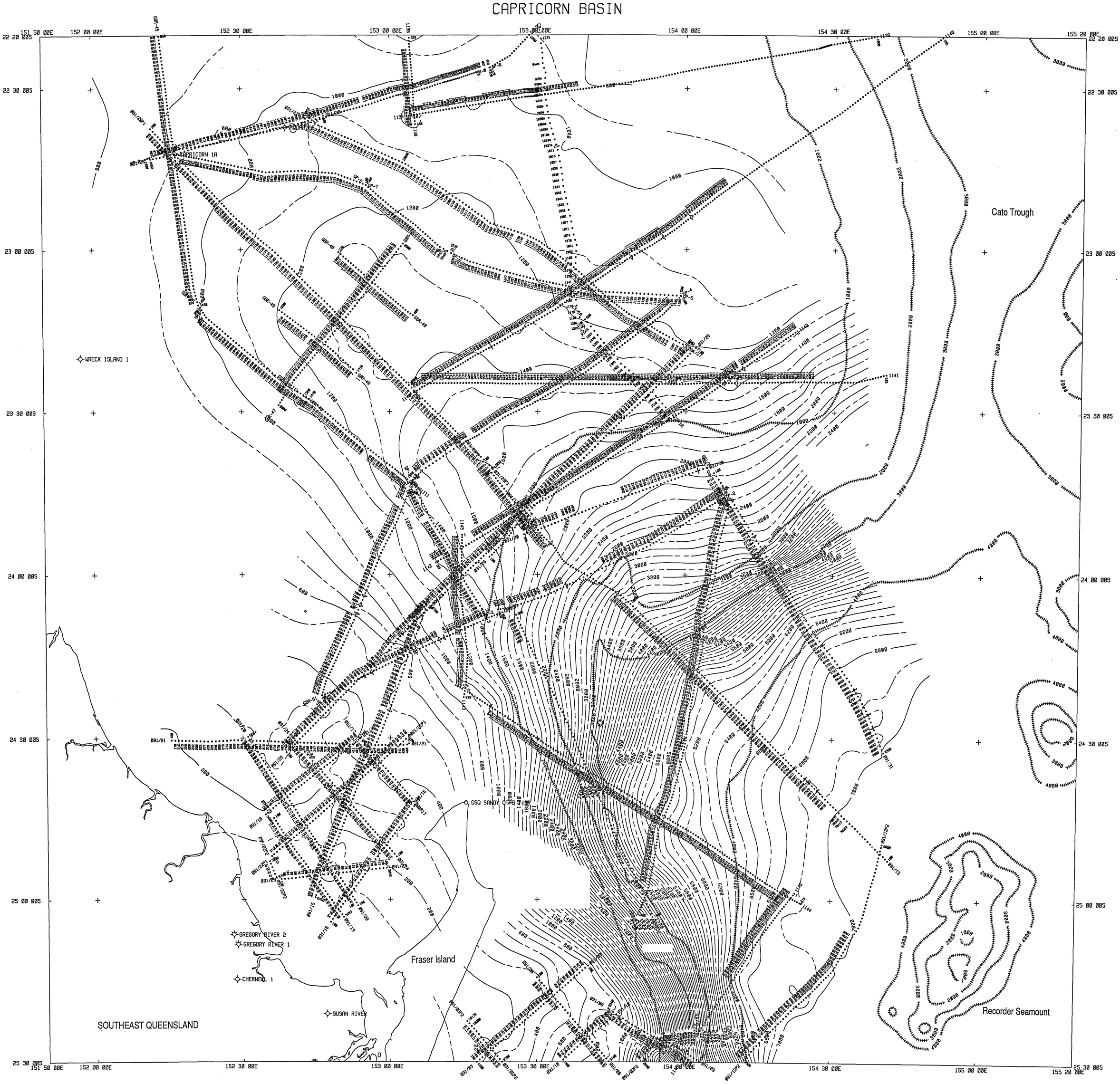
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 18

SHELF SE OF FRASER ISLAND
ISOPACH MAP
LATE OLIGOCENE - RECENT

R9400120

CAPRICORN BASIN



Posted and contour values are in milliseconds two-way time.
Contour interval is 100 milliseconds.

Bathymetry contours (hatched) are at 1000 metre interval.

1:500000
0 10 20 30 40 50
KILOMETRES

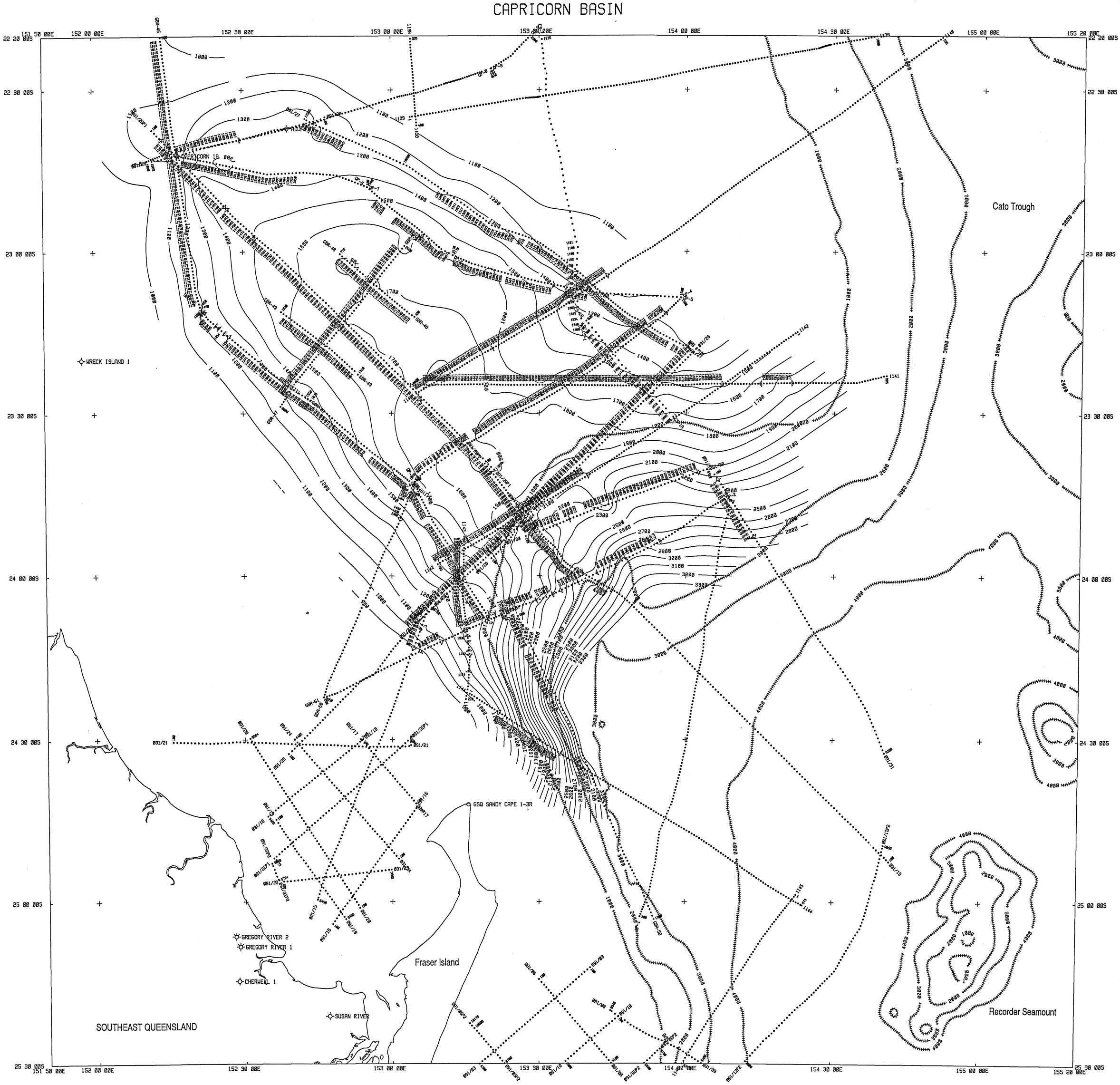
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 155 00 00E

ENCLOSURE 19

CAPRICORN & N. TASMAN BASINS
TIME STRUCTURE MAP
HORIZON TB (TOP SEQUENCE B)
EARLY OLIGOCENE UNCONFORMITY

R94001119

CAPRICORN BASIN



Posted and contour values are in milliseconds two-way time.
Contour interval is 100 milliseconds.

Bathymetry contours (hatched) are at 1000 metre interval.

1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 20

CAPRICORN & N. TASMAN BASINS
TIME STRUCTURE MAP
HORIZON TC (TOP SEQUENCE C)
NEAR MID EOCENE

R9400118

CAPRICORN BASIN

151 50 00E | 152 00 00E | 152 30 00E | 153 00 00E | 153 30 00E | 154 00 00E | 154 30 00E | 155 00 00E | 155 20 00E

22 20 00S | 22 30 00S | 23 00 00S | 23 30 00S | 24 00 00S | 24 30 00S | 25 00 00S | 25 30 00S

WRECK ISLAND 1

GSQ SANDY CAPE 1-3R

GREGORY RIVER 2

GREGORY RIVER 1

CHERWELL 1

SUSAN RIVER

Fraser Island

South East Queensland

POSTED AND CONTOUR VALUES ARE IN MILLISECONDS TWO-WAY TIME.
CONTOUR INTERVAL IS 200 MILLISECONDS.

1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

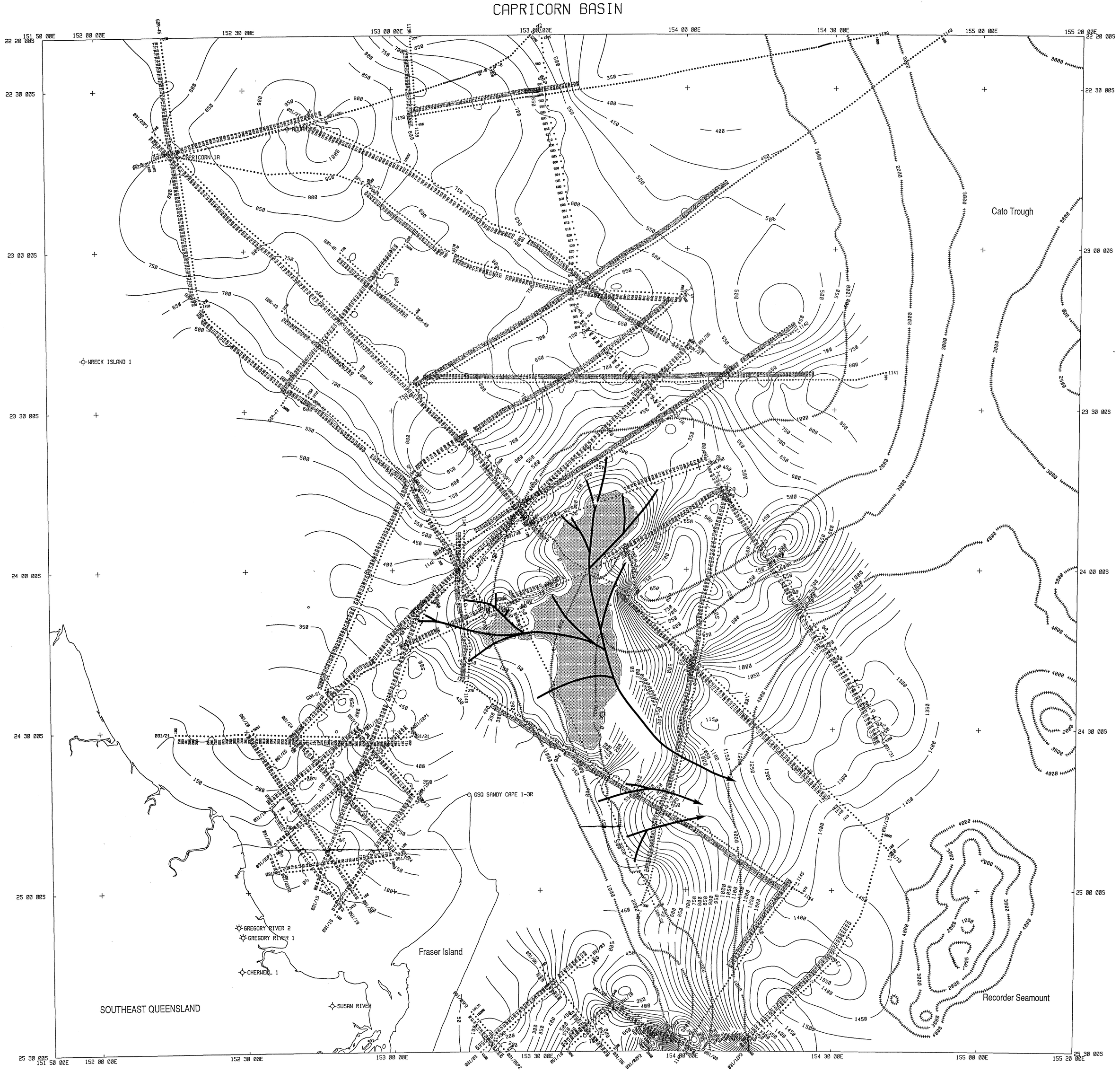
ENCLOSURE 21

CAPRICORN & N. TASMAN BASINS
TIME STRUCTURE MAP
HORIZON BE ('BASEMENT')

22/00/400

R9400117

CAPRICORN BASIN



Time thickness contours and posted values are in milliseconds.
Contour interval is 50 milliseconds.

Bathymetry contours (hatched) are at 1000 metre interval.

Thick arrowed lines represent seafloor channels and canyons.
In the patterned area, the sequence is absent due to erosion or non-deposition.

1:500000
0 10 20 30 40 50
KILOMETRES

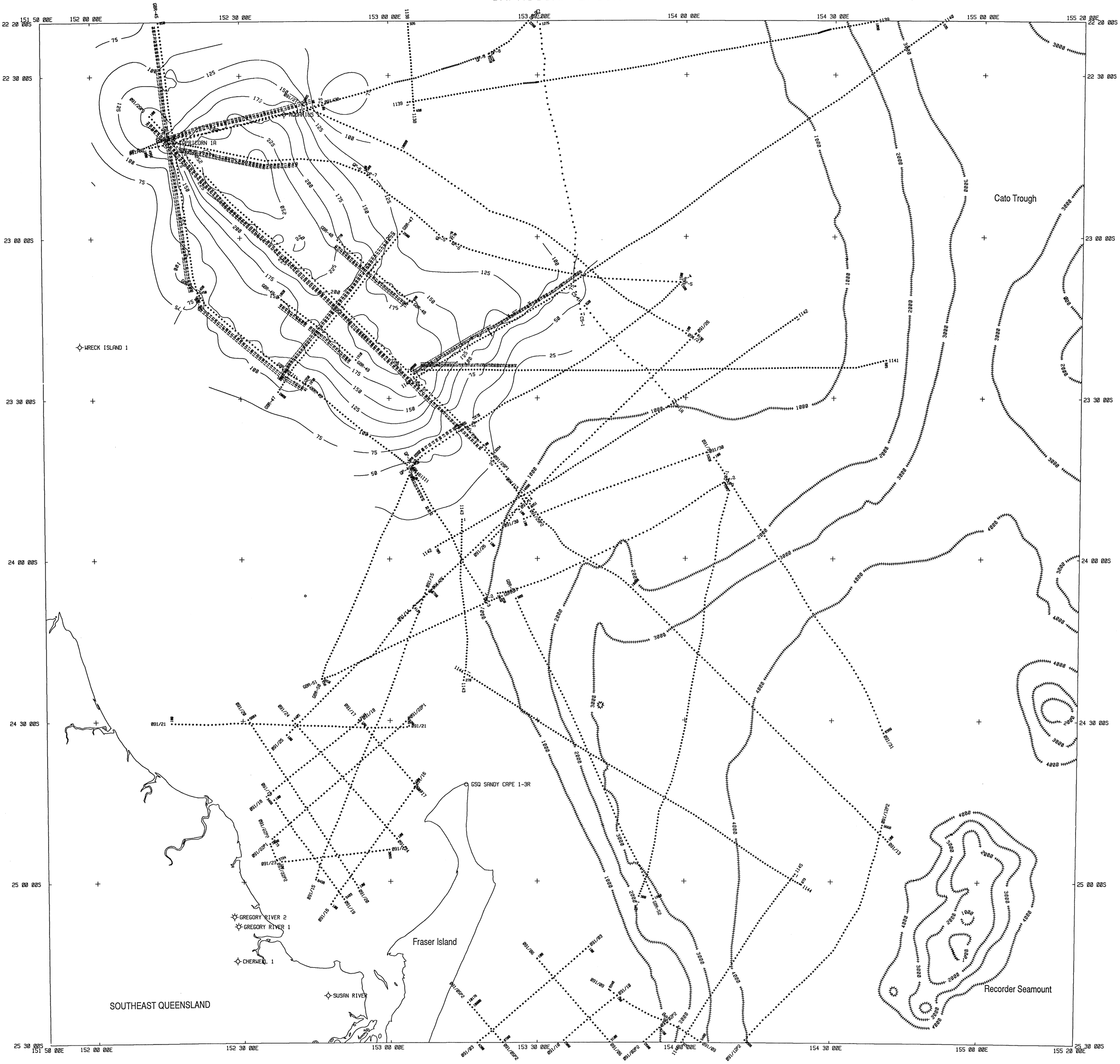
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 22

CAPRICORN & N. TASMAN BASINS
TIME THICKNESS MAP
SEQUENCE A
LATE OLIGOCENE - RECENT

R9400116

CAPRICORN BASIN



Time thickness contours and posted values are in milliseconds.
Contour interval is 25 milliseconds.

Bathymetry contours (hatched) are at 1000 metre interval.

1:500000
0 10 20 30 40 50
KILOMETRES

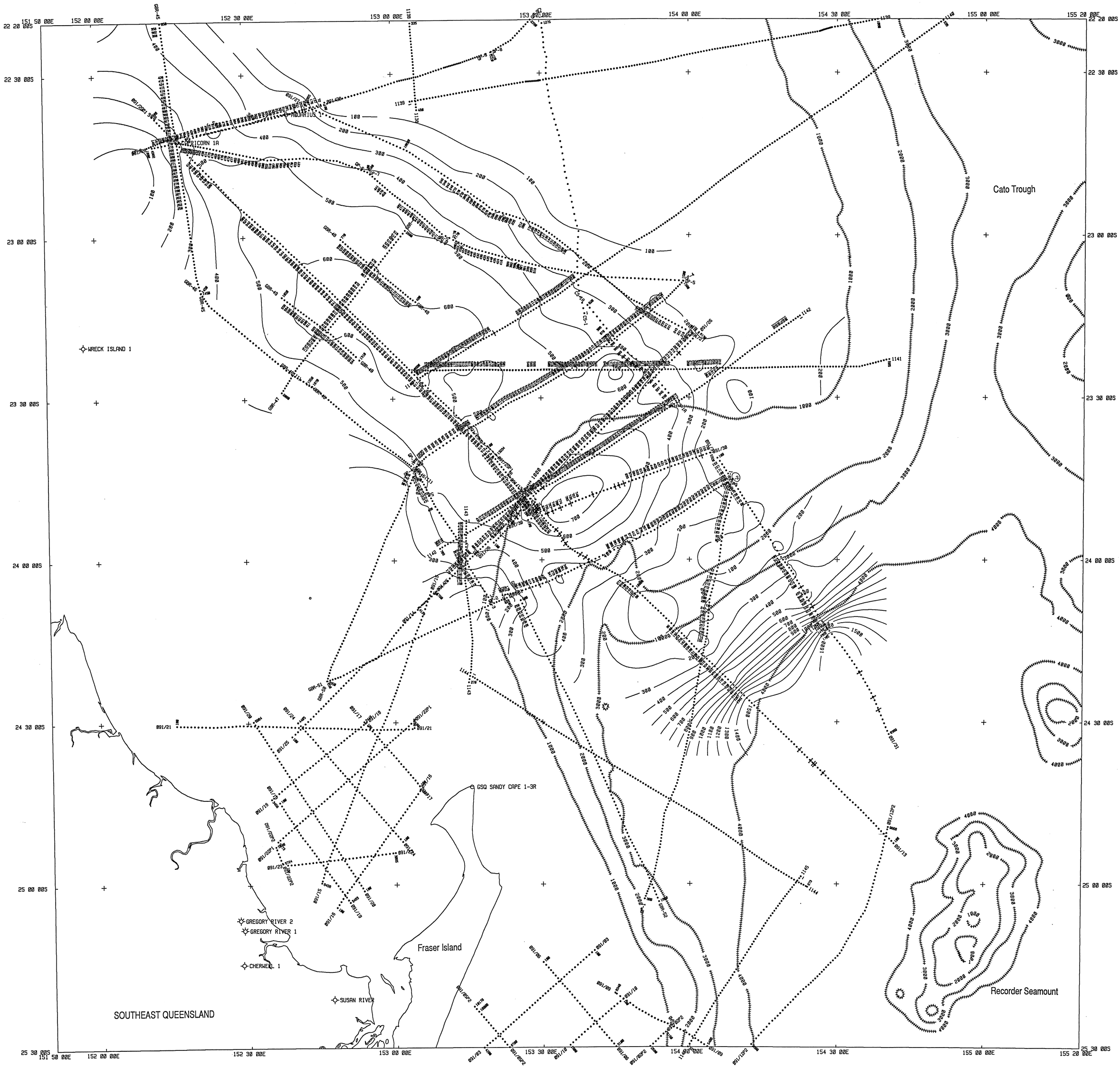
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 23

CAPRICORN BASIN
TIME THICKNESS MAP
LATE EOCENE DELTAIC SEQUENCE

R9400115

CAPRICORN BASIN



Time thickness contours and posted values are in milliseconds.
Contour interval is 100 milliseconds.

Bathymetry contours (hatched) are at 1000 metre interval.

1:500000
0 10 20 30 40 50
KILOMETRES

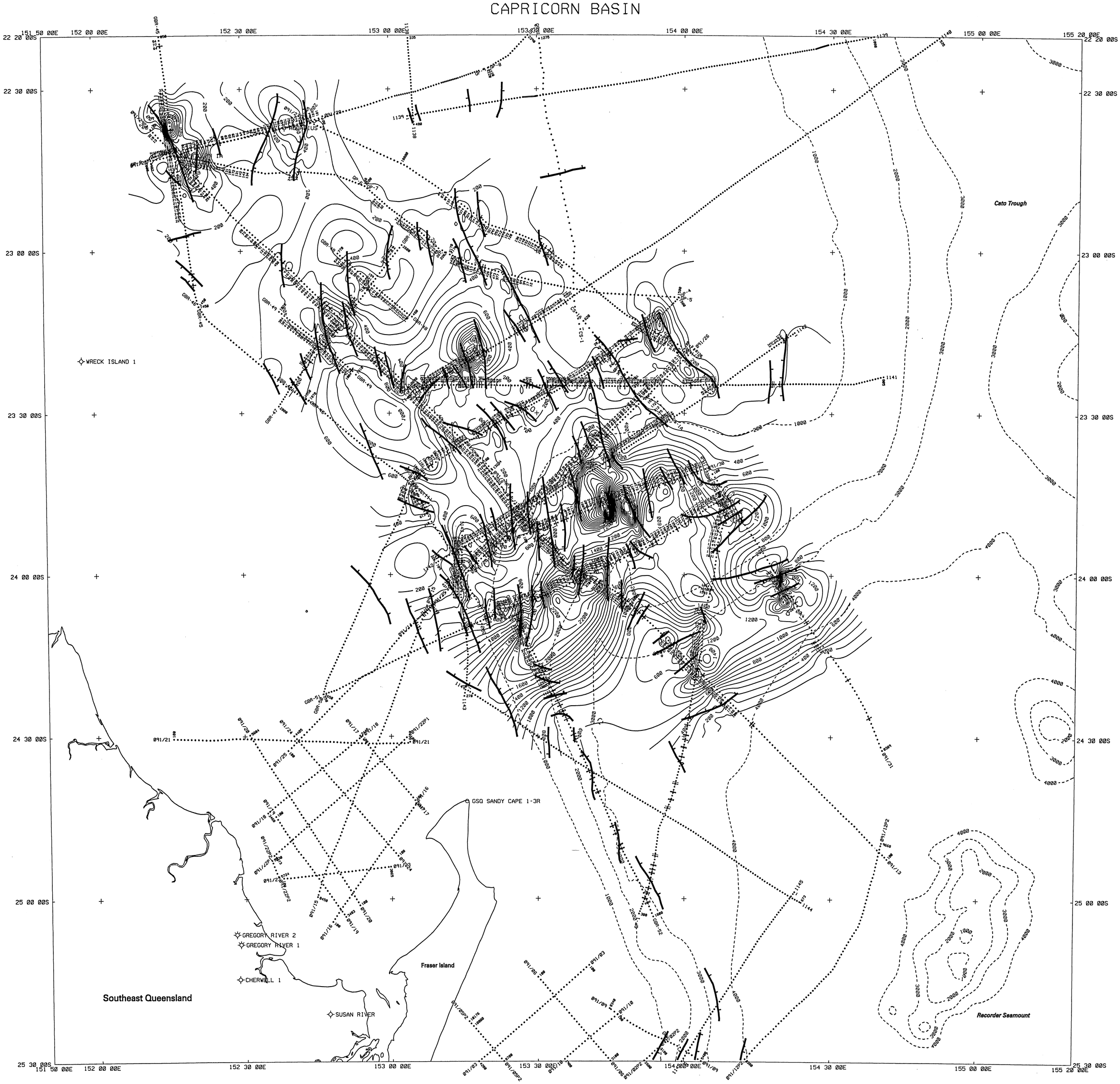
UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 24

CAPRICORN & N. TASMAN BASINS
TIME THICKNESS MAP
SEQUENCES B+C
EOCENE SHALLOW MARINE / DELTAIC
SECTION

R94001114

CAPRICORN BASIN



TIME THICKNESS CONTOURS AND POSTED VALUES ARE IN MILLISECONDS.
CONTOUR INTERVAL IS 100 MILLISECONDS.
BATHYMETRY CONTOURS (DASHED) ARE AT 1000 METRE INTERVAL.

1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 25

CAPRICORN & N. TASMAN BASINS
TIME THICKNESS MAP
SEQUENCES D-E (RIFT PHASE)
LATE CRETACEOUS - EARLY EOCENE

23/OG/401

R9400113

CAPRICORN BASIN

151 50 00E 152 00 00E 152 30 00E 153 00 00E 153 30 00E 154 00 00E 154 30 00E 155 00 00E 155 20 00E

22 20 00S
22 30 00S
23 00 00S
23 30 00S
24 00 00S
24 30 00S
25 00 00S
25 30 00S

WRECK ISLAND 1

GSQ SANDY CAPE 1-3R

GREGORY RIVER 2

GREGORY RIVER 1

CHERWELL 1

SUSAN RIVER

Fraser Island

South East Queensland

POSTED AND CONTOUR VALUES ARE IN MILLISECONDS TWO-WAY TIME.
CONTOUR INTERVAL IS 100 MILLISECONDS.

1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

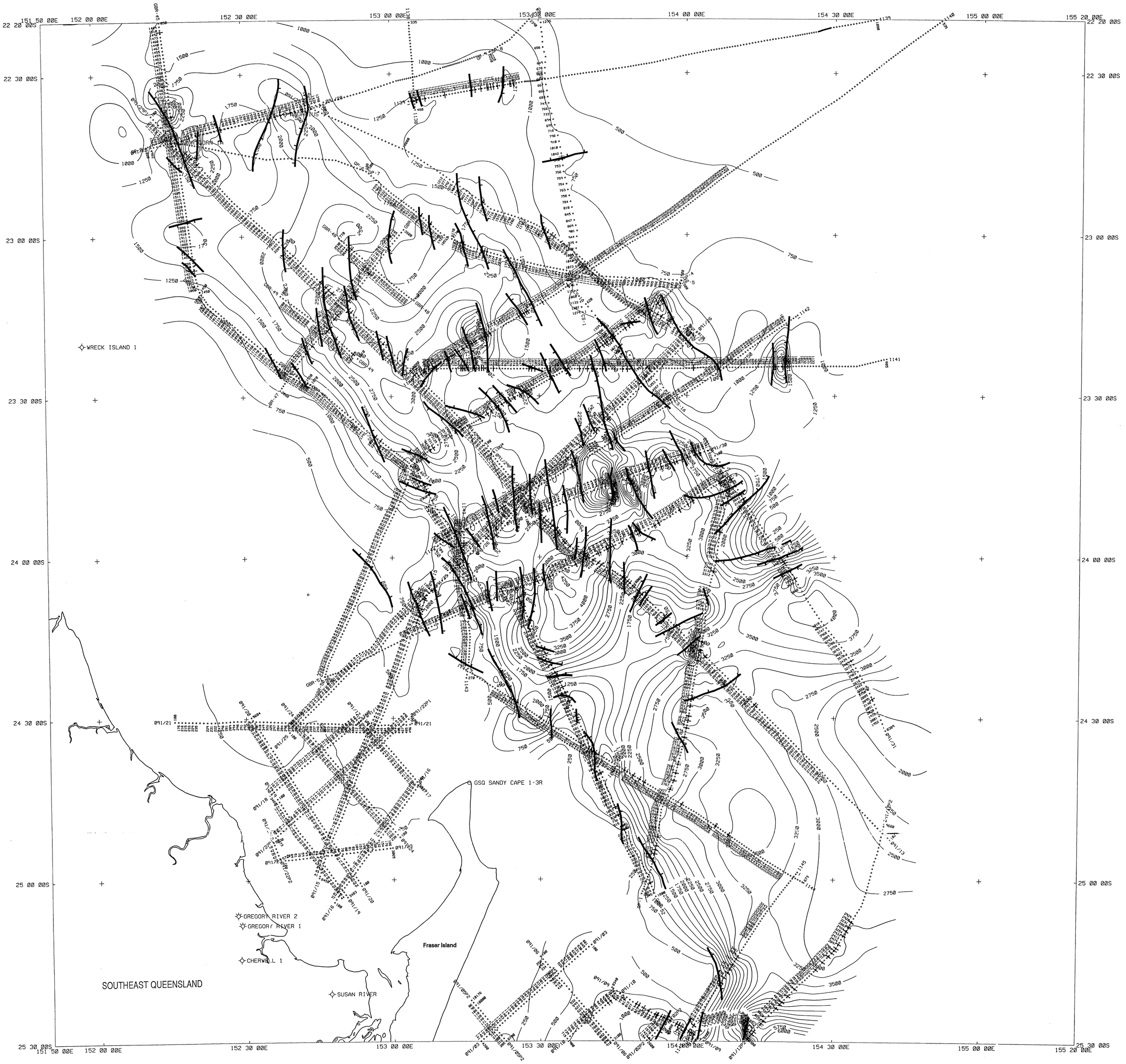
ENCLOSURE 26

CAPRICORN & N. TASMAN BASINS
TIME THICKNESS MAP
TOTAL SEDIMENTARY SECTION (A-E)
LATE CRETACEOUS - CAINOZOIC

R9400112

22/DQ/402

CAPRICORN BASIN



POSTED VALUES AND ISOPACH CONTOURS ARE IN METRES.
ISOPACH CONTOUR INTERVAL IS 250 METRES.

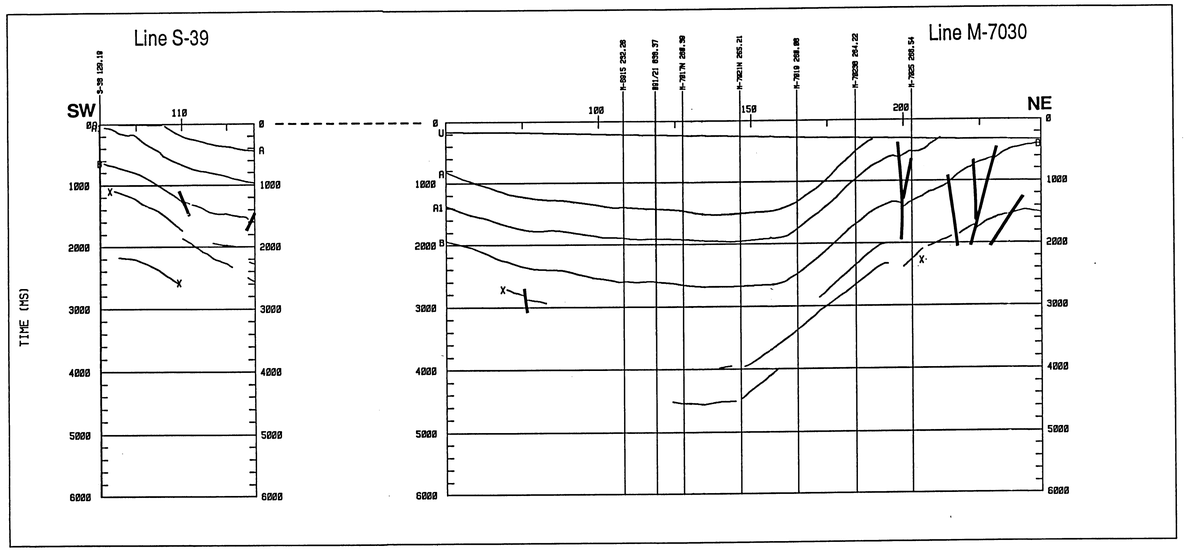
1:500000
0 10 20 30 40 50
KILOMETRES

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

ENCLOSURE 27

CAPRICORN & N. TASMAN BASINS
TOTAL SEDIMENT THICKNESS MAP
SEQUENCES A-E
LATE CRETACEOUS - CAINOZOIC

R9400111



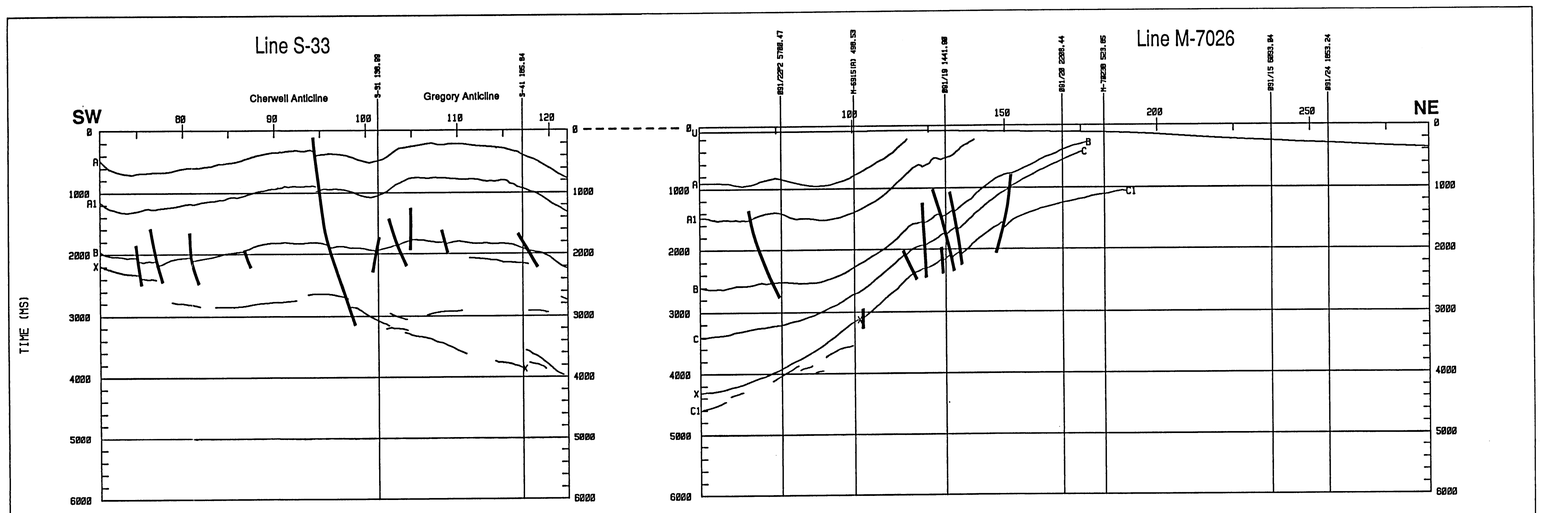
HORIZONS (Maryborough Basin)

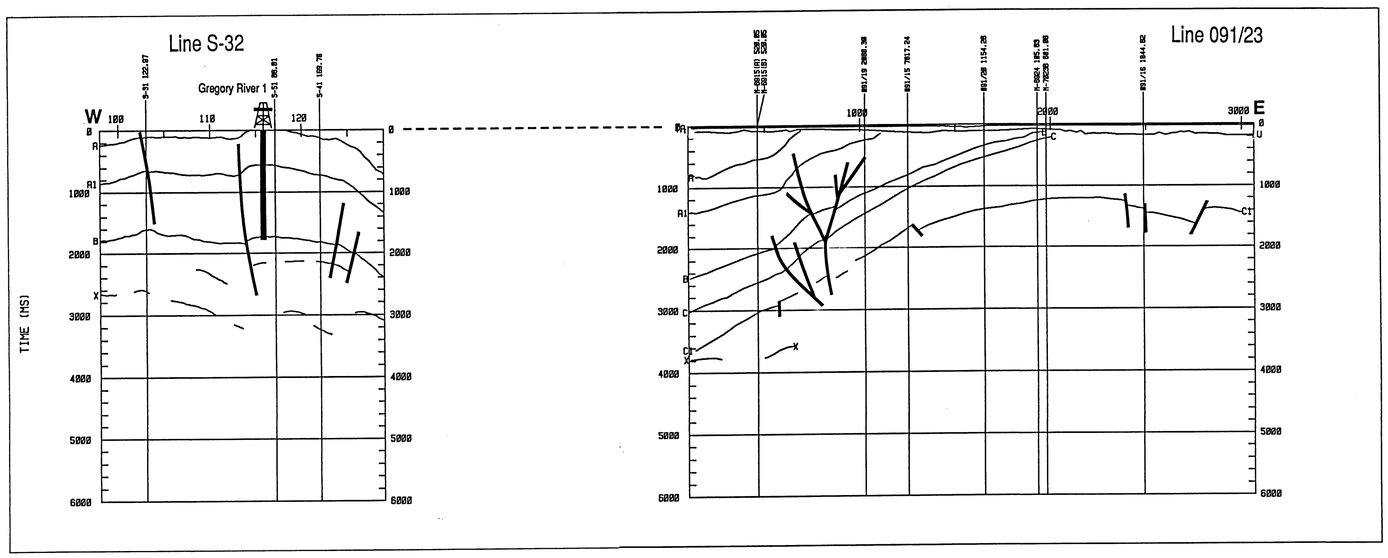
TA (Capricorn Basin nomenclature)	Seafloor
U = TB (Capricorn Basin)	Unconformity at base of Cainozoic section
A	Top of Lower Unproductive member, Burrum Coal Measures
A1	Top of Maryborough Formation.
B	Top of Grahams Creek Formation
C	Base of a sub Maryborough Formation sequence
C1	Deep 'basement' horizon
X	Uncorrelated deep reflectors

Horizontal Scale 1:200 000

0 5 10 15 20 25

KILOMETRES

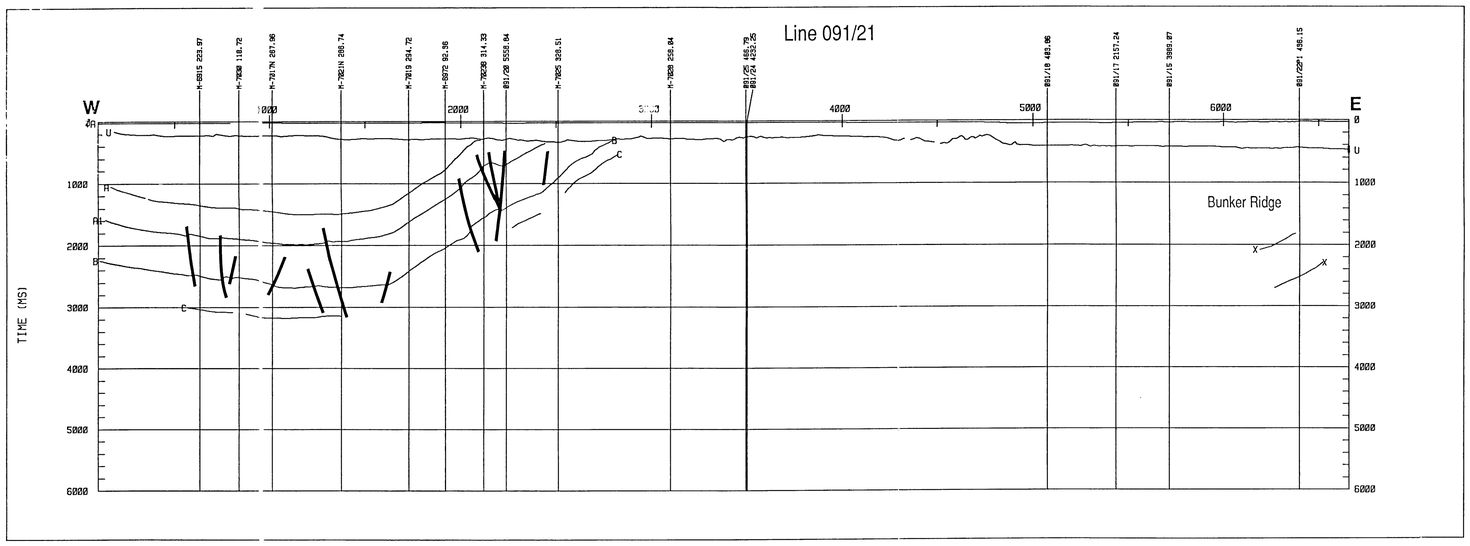


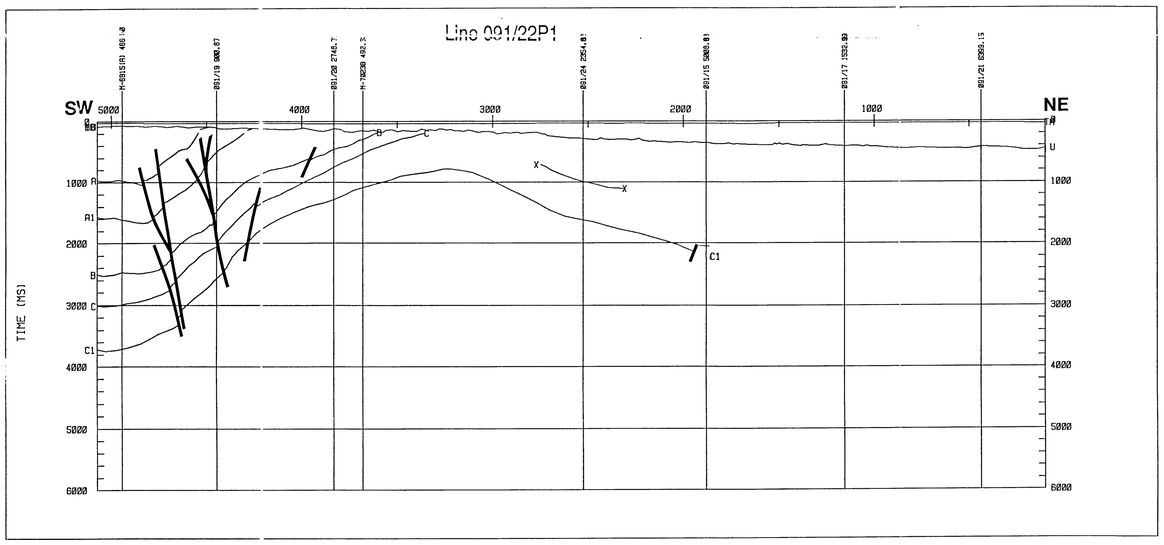


ENCLOSURE 28

MARYBOROUGH BASIN INTERPRETED SEISMIC PROFILES, ONSHORE TO OFFSHORE CORRELATIONS - LINES S-39 / M-7030, S-33 / M-7026 & S-32 / 091/23.

R9400110

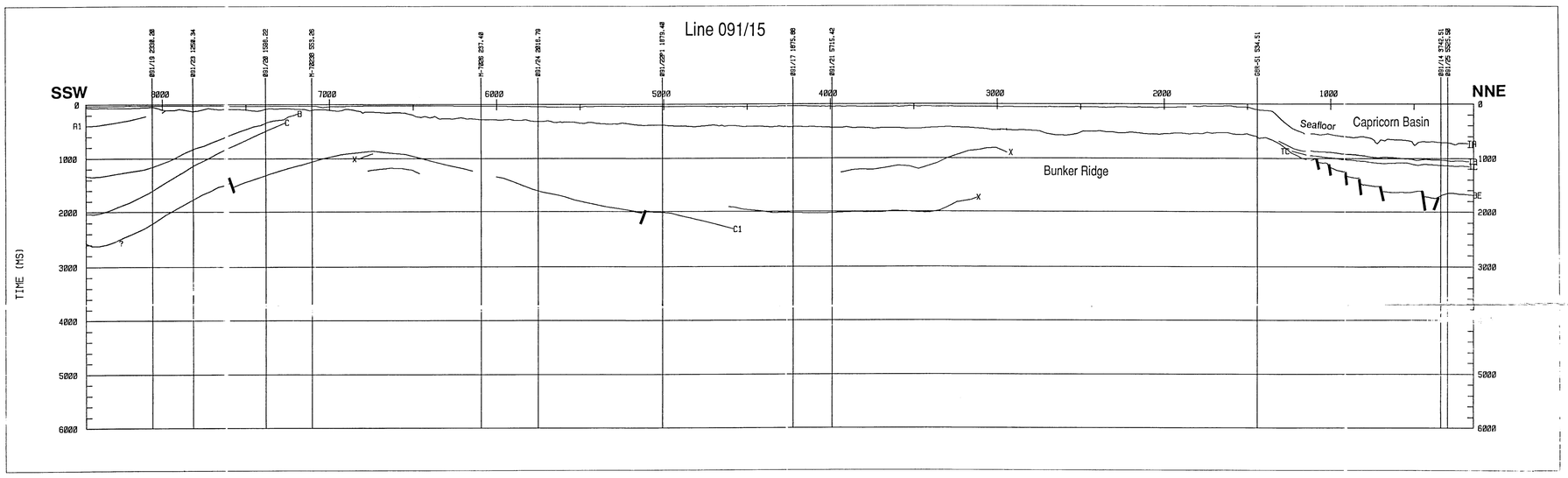


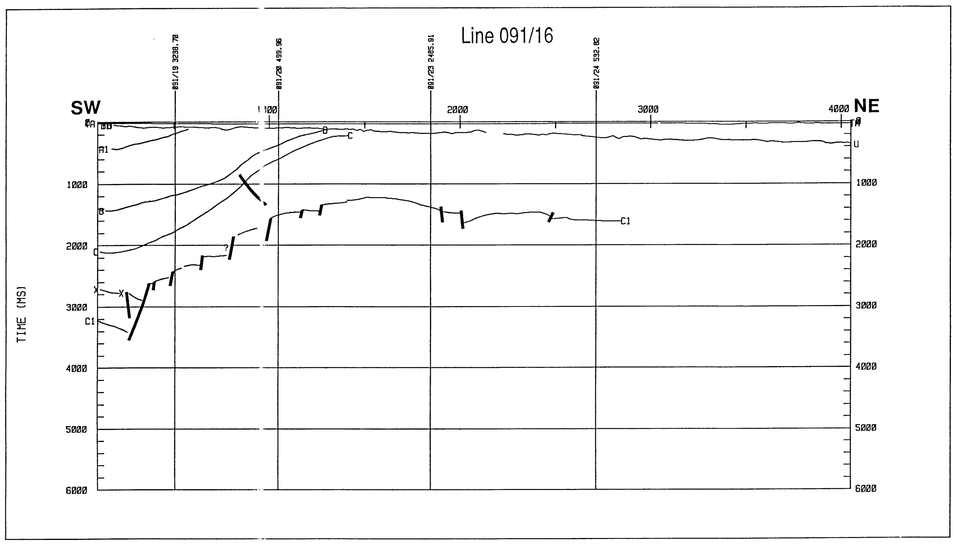


Horizontal Scale 1:200 000

0 5 10 15 20 25

KILOMETRES





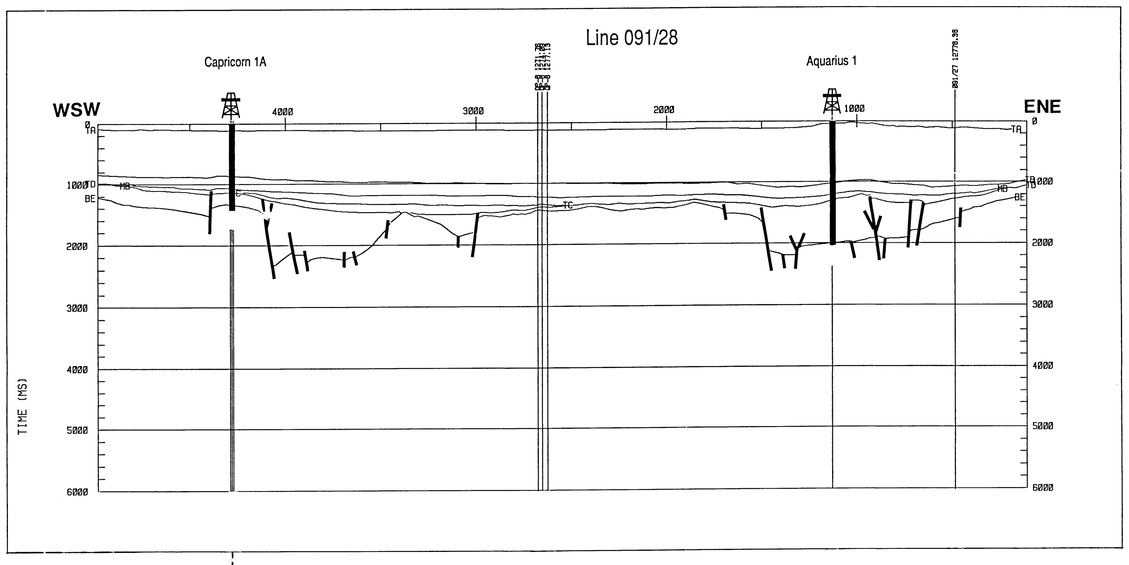
HORIZONS (Maryborough Basin)

TA (Capricorn Basin nomenclature)	Seafloor
U = TB (Capricorn Basin)	Unconformity at base of Cainozoic section
A	Top of Lower Unproductive member, Burrum Coal Measures
A1	Top of Maryborough Formation.
B	Top of Grahams Creek Formation
C	Base of a sub Maryborough Formation sequence
C1	Deep 'basement' horizon
X	Uncorrelated deep reflectors

ENCLOSURE 29

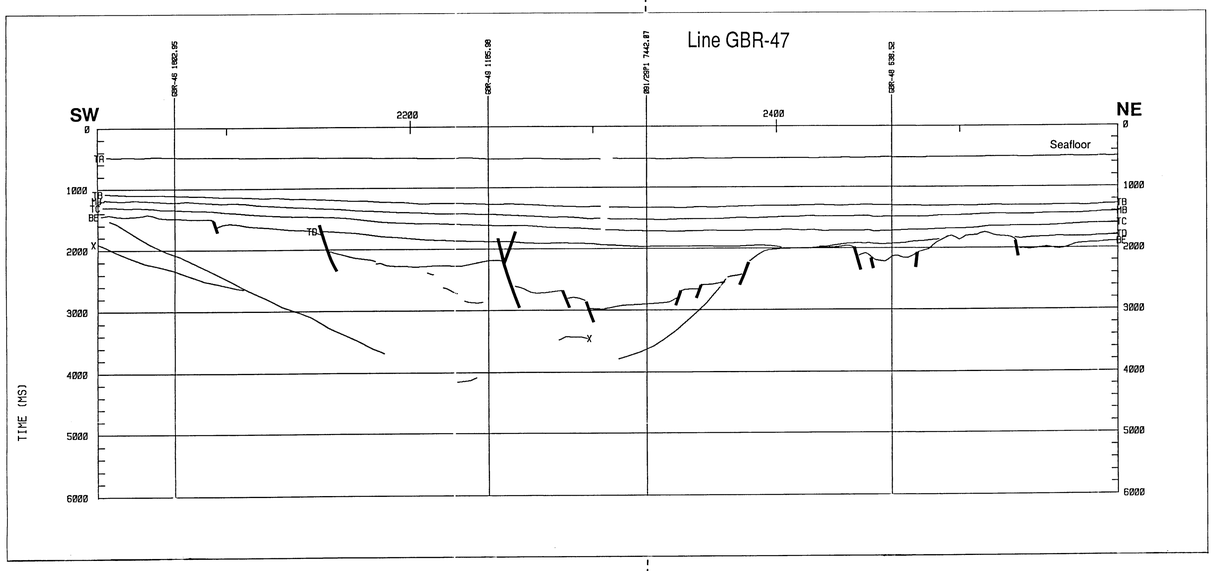
OFFSHORE MARYBOROUGH BASIN (HERVEY BAY) INTERPRETED SEISMIC PROFILES ORIENTED IN DIP DIRECTION - LINES 091/21, 091/22P1, 091/15 & 091/16.

R9400109



HORIZONS

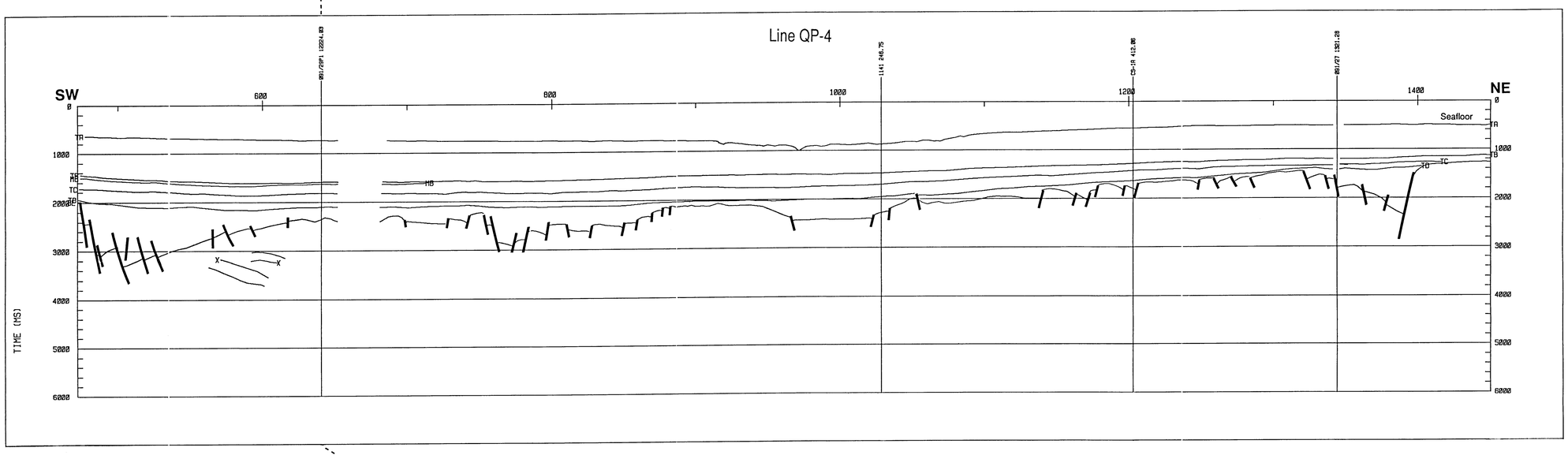
TA	Top sequence A, i.e. seafloor
TB	Top sequence B: Early Oligocene
MB	Mid B (boundary shallow marine / deltaics): Late Eocene
TC	Top sequence C: late Middle Eocene
TD	Top sequence D: Early Eocene
TE	Top sequence E: Early Paleocene
BE	Base sequence E: Late Cretaceous
X	Uncorrelated deep reflectors

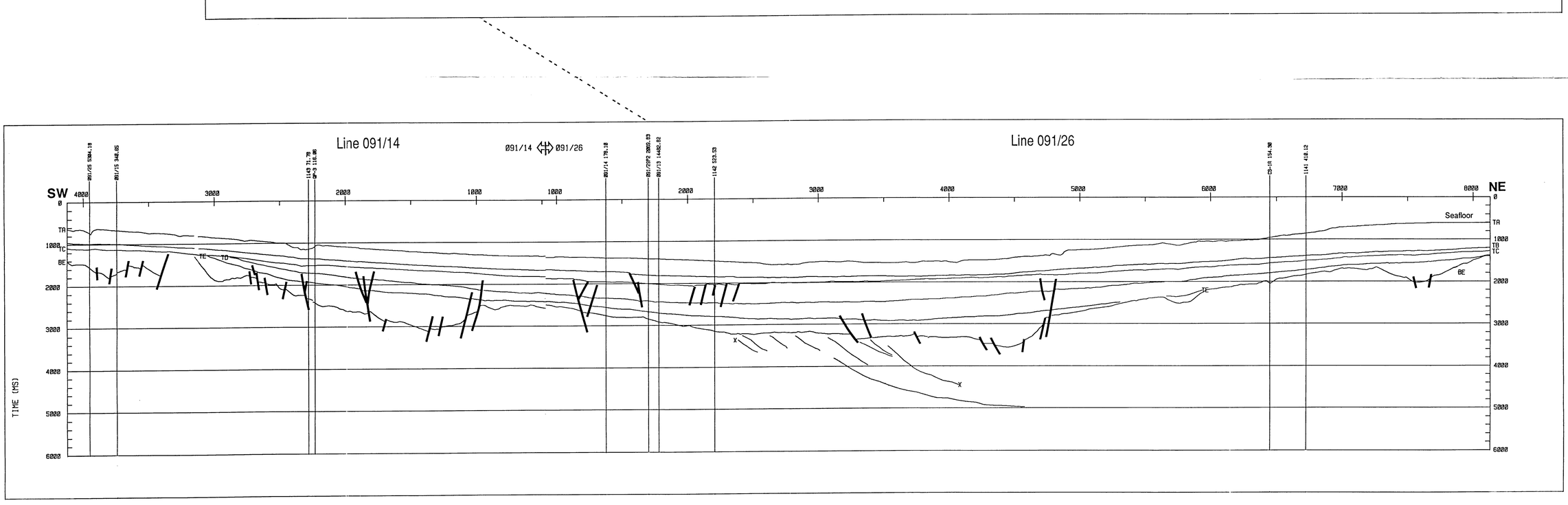


Horizontal Scale 1:200 000

0 5 10 15 20 25

KILOMETRES

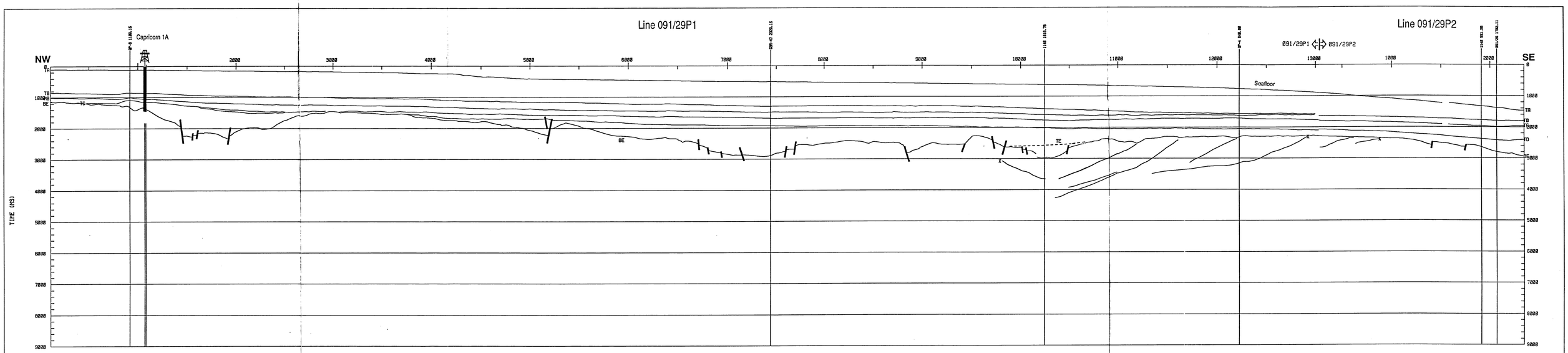




ENCLOSURE 30

TRANS CAPRICORN BASIN INTERPRETED SEISMIC PROFILES - LINES 091/28, GBR-47, QP-4, 091/14 & 091/26.

R9400108



Horizontal Scale 1:200 000

0 5 10 15 20 25

KILOMETRES

HORIZONS

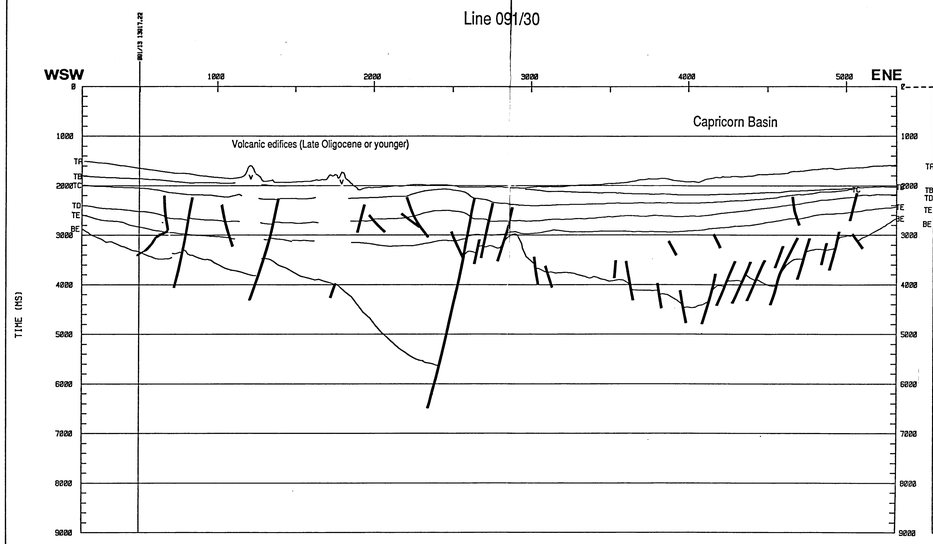
TA	Top sequence A, i.e. seafloor
TB	Top sequence B: Early Oligocene
MB	Mid B (boundary shallow marine / deltaics): Late Eocene
TC	Top sequence C: late Middle Eocene
TD	Top sequence D: Early Eocene
TE	Top sequence E: Early Paleocene
BE	Base sequence E: Late Cretaceous
X	Uncorrelated deep reflectors

ENCLOSURE 31

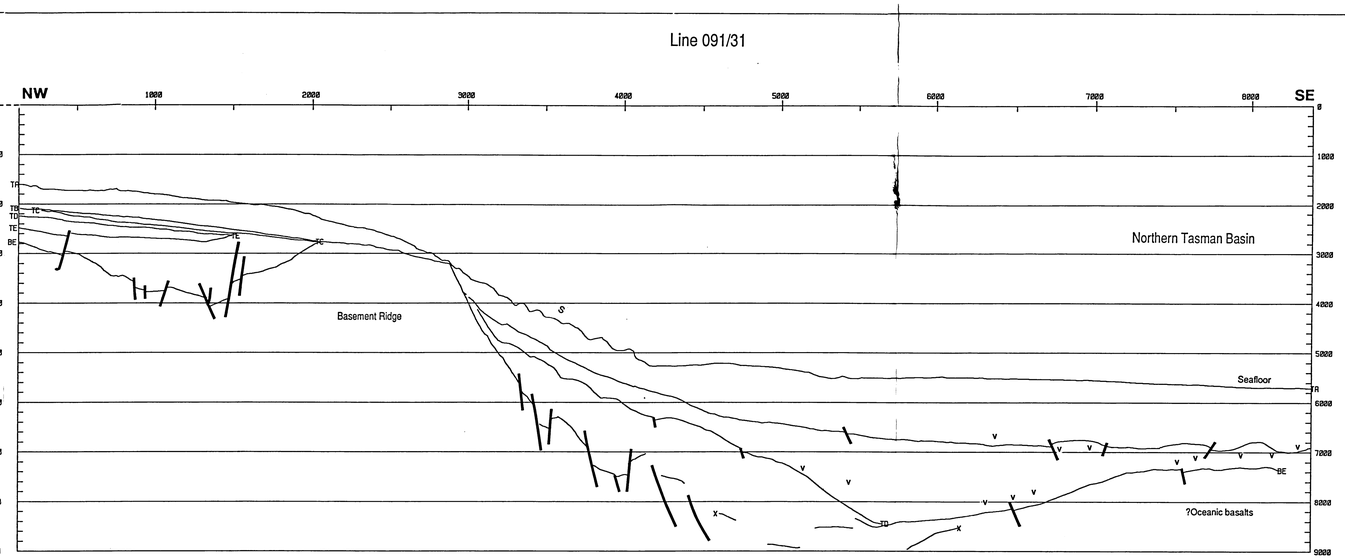
AXIAL INTERPRETED SEISMIC PROFILE (LINES 091/29P1 & 091/29P2), CAPRICORN BASIN.

R9400107

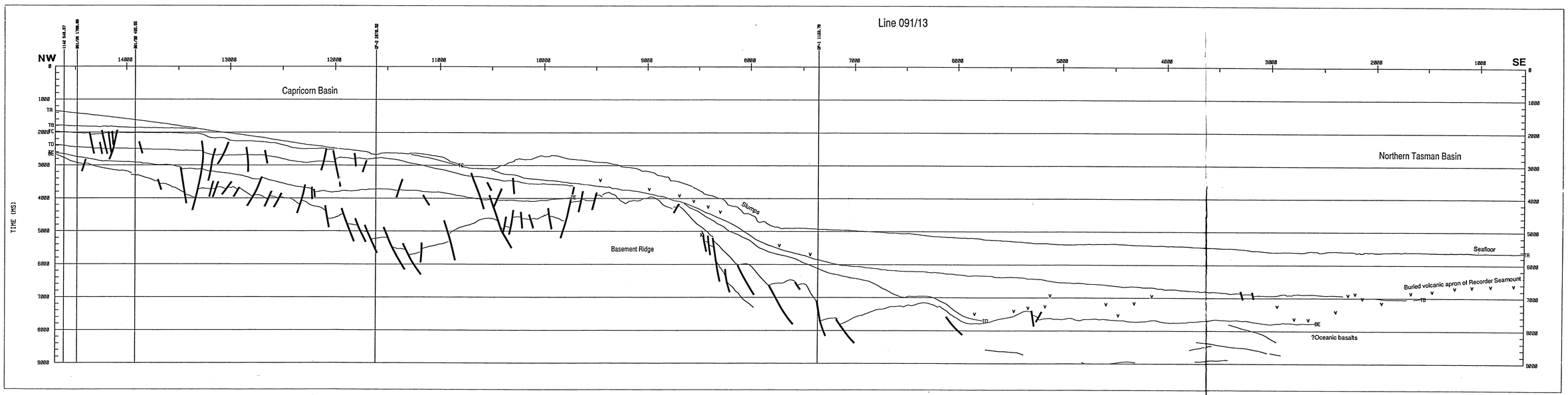
Line 091/30



Line 091/31



Line 091/13



Horizontal Scale 1:200 000

0 5 10 15 20 25

KILOMETRES

HORIZONS

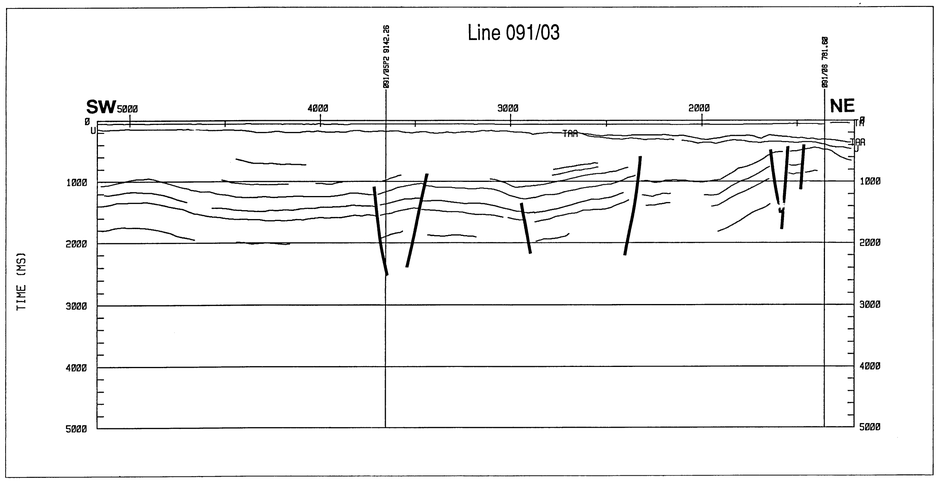
TA	Top sequence A, i.e. seafloor
TB	Top sequence B: Early Oligocene
TC	Top sequence C: late Middle Eocene
TD	Top sequence D: Early Eocene
TE	Top sequence E: Early Paleocene
BE	Base sequence E: Late Cretaceous
X	Uncorrelated deep reflectors

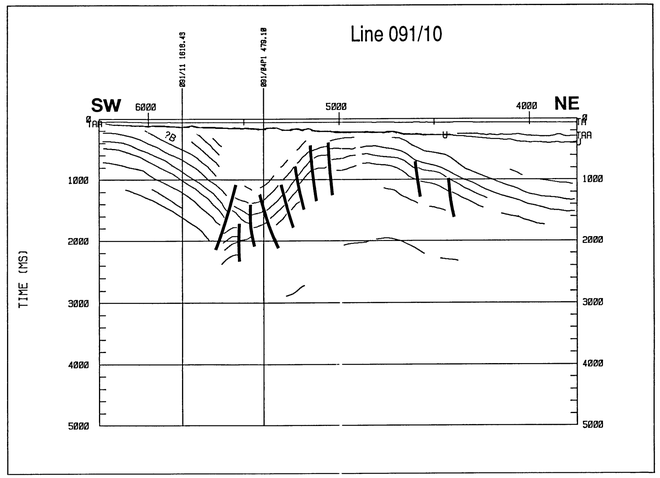
v Volcanics

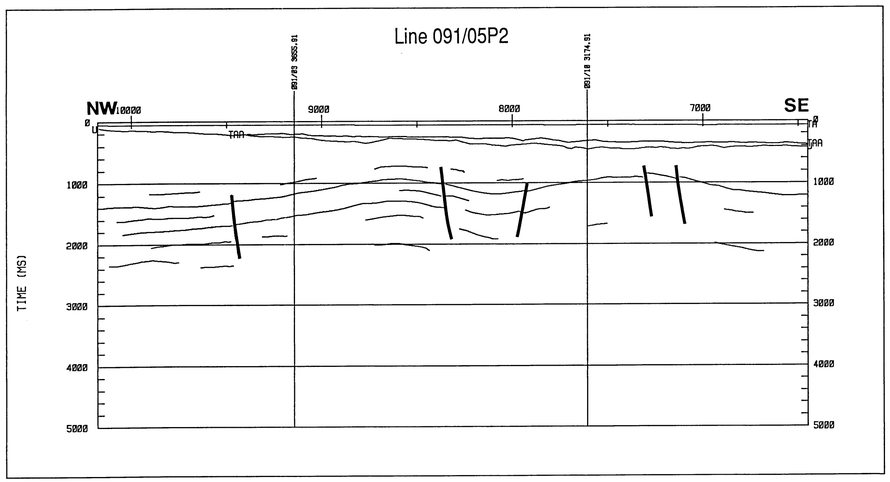
ENCLOSURE 32

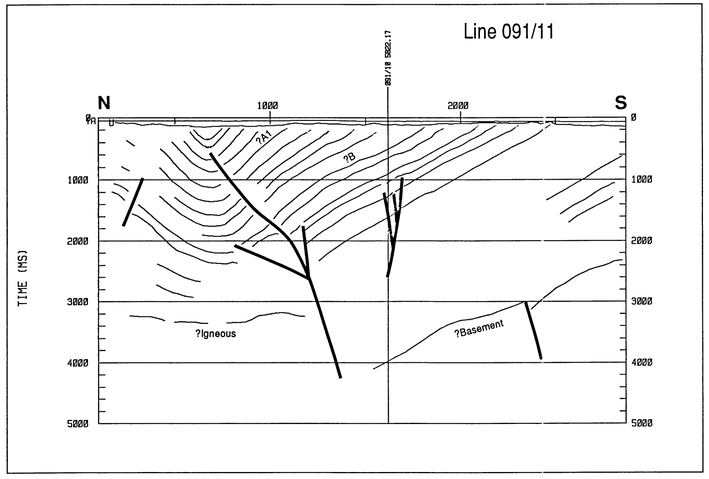
INTERPRETED SEISMIC PROFILES AT AND ACROSS THE SOUTHEASTERN MARGIN OF THE CAPRICORN BASIN - LINES 091/30, 091/31 & 091/13.

R9400106









Horizontal Scale 1:200 000



HORIZONS (Maryborough Basin)

TA (Capricorn Basin nomenclature)	Seafloor
TAA	Late Tertiary (? late Middle Miocene) unconformity
U ≡ TB (Capricorn Basin)	Unconformity at base of Cainozoic section
A1	Top of Maryborough Formation.
B	Top of Grahams Creek Formation

ENCLOSURE 33

INTERPRETED SEISMIC PROFILES ACROSS THE CONTINENTAL SHELF SOUTHEAST OF FRASER ISLAND - PARTS OF LINES 091/03, 091/05P2, 091/10 AND 091/11.

R9400105

SHELF SE OF FRASER ISLAND

153 00 00E | 153 30 00E | 154 00 00E | 154 17 00E

25 07 00S | 25 30 00S | 26 00 00S | 26 30 00S | 26 52 00S

Fraser Island

Urangan Synclinorium

Susan Anticline

Burrum Syncline

Wide Bay

RJd outcrop

JKg outcrop

Eastern limit of aeromagnetics

Caloundra

? ~ 2.5 s (twt) syn / post rift section

0 5 10 15 20 25 KILOMETRES 1:250000

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
AUSTRALIAN NATIONAL SPHEROID
CENTRAL MERIDIAN 153 00 00E

Datum: sea level

ENCLOSURE 34

BEDROCK STRUCTURE BENEATH THE CONTINENTAL SHELF SOUTHEAST OF FRASER ISLAND

- Sub-Tertiary (bedrock) refractor velocity > 4600 m/s
- Gravity low anomaly or anomaly trend
- Areas of short wavelength aeromagnetic anomalies
- Areas of high amplitude aeromagnetic anomalies (* indicates major high)
- Normal fault
- Reverse fault
- Syncline
- Anticline
- Aeromagnetic lineation
- [ ] Profile limits (Enclosure 33)
- Stratigraphic bore, bedrock geology
  - a) Km - Maryborough Formation
  - b) JKg - Grahams Creek Formation
  - c) RJd - Ducklnwilla Group
- Bathymetry contour interval is 1000 metres

R9400104