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THE STRUCTURE OF THE NORTH TASMAN SEA

by

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FOREWORD

This paper was presented at the Second International Conference on Geophysics of the Earth and the Oceans held at the University of Sydney on 15 to 19 January 1973.

SUMMARY

A 20 000-nautical-mile, multisensor reconnaissance survey by the Bureau of Mineral Resources (BMR) mainly in the north Tasman Sea has provided better definition of many of the major geophysical features, and has allowed speculation on some aspects of the tectonic evolution of the Tasman Sea region.

The continental margin consists of a narrow shelf and a steeper-than-normal slope, which suggests a tectonic origin for the southeastern margin of Australia. The undulating 'oceanic' basement of the abyssal plain is overlain by about 750 m of sediments, thickening to greater than 1 km at the base of the continental slope. The north-trending Dampier Ridge, which rises 2.5 km above the abyssal plain, is separated from Lord Howe Rise by basins containing up to 2 km of sediment.

A structural interpretation supports a two-stage formation for the Tasman Basin. The first was associated with the initial separation of Lord Howe Rise and Australia owing to rotational spreading in the central Tasman Sea. This resulted in the development of a volcanic ridge, which was the embryo of the Dampier Ridge, in the narrow rift in the north Tasman Sea. The second was associated with either rifting along the margin of Australia or an increase in the rate of rotational spreading, resulting in the formation of the present abyssal plain and the asymmetric position of the Dampier Ridge between Lord Howe Rise and Australia. The form of the north Tasman Basin has been controlled by the northeast movement of the Dampier Ridge/Lord Howe Rise block and by structural trends similar to those of the Tasman Geosyncline.

INTRODUCTION

BMR has just completed a 2-year contract survey around the continental margin of Australia; it consisted of about 90 000 nautical miles of systematic traversing. Seismic reflection, bathymetric, gravity, and magnetic data were collected continuously and about 250 sonobuoy refraction probes were made. Navigation was by satellite/sonar-doppler backed up by two ship's logs and a VLF/Omega system.

Although digital bathymetric, gravity, and magnetic data were collected at 10-second sampling intervals, the contour maps presented herein were hand-contoured on board ship from hourly values computed manually before final processing.

Plate 1 shows the distribution of traverses in the Tasman Sea area, where BMR has traversed about 20 000 nautical miles, most of it in the north Tasman Basin, with only a few regional traverses in the central Tasman Basin.

BATHYMETRY

Only a brief description of the major bathymetric provinces will be given here as many pages have been devoted to this task in the published literature. The provinces are easily discernible on the bathymetric map in Plate 2.

The continental margin consists of a narrow shelf, which varies in width from about 40 km in the south to about 100 km in the north near Fraser Island, and a steeper-than-normal slope, which often has a convex profile. The average slope varies from 4° to 8° but locally may be as much as 20°; this steep slope is indicative of a rift origin for the margin. The slope is cut by many down-slope canyons, which are generally small; however, in the Moreton Island/Stradbroke Island area there is quite an extensive canyon system. There are also many small canyons running parallel to the slope and these are probably indicative of strong contour currents.

North of 30°S a poorly developed continental rise occurs and reaches maximum extent in the area west of the Queensland Guyot.

Probably the most striking bathymetric feature is the Tasman Basin, which is the area of sea-floor ranging from 4400 to 4800 metres in depth and lying between the continental margin and the Dampier Ridge in the north and the continental margin and Lord Howe Rise in the south. The north Tasman Basin, whose eastern margin has a strong en echelon character, is about 250 km wide whereas the central Tasman Basin is up to 1000 km in width. Conolly (1969) subdivided the Tasman Basin into three provinces on the basis of bottom topography:

(1) the abyssal plain, which is about 200 to 300 km wide and slopes gently to the south parallel to the continental margin

(2) the undulating 'swale' province, which lies east of the abyssal plain

(3) the abyssal hills province, which lies east of the swales.

The Dampier Ridge is a north-trending ridge about 100 km wide, and lies east of the north Tasman Basin between latitudes 26°S and 33°S; it reaches a maximum crest height of about 1800 m below sea level, with an average of about 2500 m. It is separated from Lord Howe Rise by the Middleton Basin in the north and the Lord Howe Basin in the south. These basins lie at depths of about 3400 m and 3900 m respectively.

The only other major bathymetric features in the area are the approximately north-trending Tasmantid and Lord Howe Island seamount chains. The guyots and seamounts of the Tasmantid chain stand 1400 to 4400 m above the Tasman Basin floor, whereas in the Lord Howe Island chain most of the seamounts occur as reefs and islands along the foothills of Lord Howe Rise.

Plate 3 shows schematic profiles across the north and central Tasman Basin (sections X-X' and Y-Y', Plate 2) and illustrates the difference in character between these two areas. The rugged basal reflector is the basement surface and the other lines above this indicate prominent reflectors within the sediments. Several points are illustrated by these profiles:

1. a more rugged basement, which often occurs as abyssal hills, beneath the abyssal plain in the north Tasman Basin
2. a thicker section of good reflectors in the abyssal plain of the central Tasman Basin than in the north Tasman Basin, where the sediments are more transparent
3. the rugged basement of the Dampier Ridge
4. the thickness of sediment in the Lord Howe Basin, which contains several good reflectors
5. the prominent reflector lying about halfway between the basement surface and the sea-floor of the abyssal plain in the central Tasman Basin. There is often a vague and disrupted reflector apparent in the swale and abyssal hills province and this may be similar to that of the abyssal plain
6. in the central Tasman Basin, basement dips west from abyssal hills which are probably part of the northwest trending basement ridge that runs across the central Tasman Basin (Ringis, 1970; Hayes & Ringis, 1972).

STRUCTURE

The seismic sections described below have been chosen to illustrate the general structure and sedimentary character of the area. Their locations are shown in Plate 2.

Abyssal Plain. Sections A, B, and C (Plate 4) show how the character of the abyssal plain changes from south to north. Section A was obtained on a north-south line at longitude 151°E just east of Bass Strait. It shows 1 to 2 seconds (two-way time) of sediment overlying a relatively smooth, undulating basement topography. The upper ½ to 1 second of sediment consists of good reflectors, which are underlain by an acoustically transparent zone containing only one prominent reflector.

b

Section B was obtained on an east-west line at latitude 34°30' east of Sydney. It depicts a similar sedimentary section to that of Section A; however, the basement topography is considerably more rugged. The good reflecting sediments, which again overlie a transparent zone, are draped over basement highs.

Section C was obtained on a north-south line at longitude 155°E east of Sugarloaf Point. It illustrates several features common to the north Tasman Basin:

(1) relatively rugged basement topography

(2) some basement highs occur as abyssal highs

(3) the sediments are generally quite acoustically transparent except for the upper few milliseconds.

Section C also shows damming of sediments by abyssal hills and the presence of a pelagic blanket over the hills.

BMR seismic traverses, which are 20 nautical miles apart, give no evidence to suggest the presence of a basement ridge in the north Tasman Basin. Basement highs are generally not correlatable from traverse to traverse and are probably local features which together make up the relatively rugged basement topography.

Sections D and E (Plate 5) illustrate some interesting sedimentary structures occurring on the abyssal plain in the north Tasman Basin. Section D was obtained on an east-west traverse at latitude 28°30'S, and runs from the continental rise in the west to the Brittania Guyot in the east. The section shows a 0.5-second pile of good reflecting sediments overlying about 1.5 seconds of more acoustically transparent sediment, which contains at least two prominent reflectors. The presence of channels and levees on each side of the pile indicates the presence of fairly strong deep-sea contour currents. This pile of sediment extends south as a ridge and is evident on Section E.

Section E was obtained on an east-west traverse at latitude 29°30'S and runs east from the shelf. It illustrates the general character of the flat-based ridge of sediment, which has a maximum elevation above the abyssal-plain floor of 200 m and peters out south of 31°S. This suggests that the ridge was formed as a result of southerly transport of sediment by deep-sea contour currents. The sediment source was probably the large canyon system east of Moreton Bay and Cape Byron.

Section E also shows a typically steep continental slope profile.

Dampier Ridge. Section F (Plate 6) was obtained on an east-west traverse across the aseismic Dampier Ridge at about latitude 32°E. The section shows both the characteristically rugged basement of this feature, on which basement highs or intrusions often protrude from the seafloor, and the thick sedimentary section of the Lord Howe Basin. The ridge is covered with an average of 500 m of acoustically, fairly transparent sediment, with up to 1 km of sediment in basement lows. In several places the western margin of the Dampier Ridge appears to be fault-controlled, and locally slopes from 20 to 25° occur in these areas. The character of the seismic sections over the ridge and the magnetic expression of small basement highs suggest that the basement is volcanic. It is difficult to tell if the basement surface is continuous with that of the north Tasman Basin.

Several possibilities for the origin of the Dampier Ridge can and have been put forward:

(1) a piece of uplifted abyssal plain

(2) an extinct mid-oceanic ridge (Van der Linden, 1969)

(3) a piece of submerged continental crust left behind when Lord Howe Rise and Australia separated

(4) an intrusive complex or volcanic ridge formed in the initial rift between Lord Howe Rise and Australia.

I favour the last of these possibilities as the seismic and magnetic information, and the crustal-structure interpretations (Shor et al., 1971; Woodward and Hunt, 1971) throw doubt on the others.

Section G and H (Plate 7) illustrate a feature that occurs in both the central and north Tasman Basin. Section G was obtained on a northeast-southwest traverse across the central Tasman Basin at about latitude 37°S. It shows the contact between the good reflecting sediments of the abyssal plain to the west and the relatively transparent sediments of the swale area to the east. The important points brought out by this section are:

(1) the basement surface dips to the west and becomes rougher west of the swale area

(2) the presence of a prominent central reflector in the abyssal plain area and a vague central reflector in the swale area; these may be the same reflector.

Section H was obtained on an east-west traverse in the north Tasman Basin at latitude 28°30'S. The section shows a similar feature to Section G, although there is some ponding of the good reflecting sediment of the abyssal plain against the Brittania Guyot to the west.

This change in the character of the sediments can be traced into the north Tasman Basin as far north as latitude 28°30'S, where it runs into the faulted margin of the Dampier Ridge. Although the change in the basement character near the swale abyssal-plain boundary is often slight, it is quite marked on some lines in the north Tasman Basin. I suggest that this feature not only indicates a change in the sedimentary style due to the distance from the continental margin, but is also of tectonic significance in the north Tasman Basin and perhaps part of the central Tasman Basin.

GRAVITY FIELD AND CRUSTAL STRUCTURE

The free-air anomaly map is shown in Plate 8. The free-air anomalies generally vary slightly about zero except for areas of local relief such as guyots and seamounts. This suggests that the north Tasman Basin is close to regional isostatic equilibrium, but as most of the area has a small negative free-air anomaly, it is probably slightly overcompensated.

Plate 9 is the Bouguer-anomaly map, which was computed using a density of 2.2 gm/cm^3 for the water layer in an effort to remove the effect of the sediment-water interface. If this was effective the major causes of Bouguer-anomaly variation should be the basement topography and changes in the depth to the base of the crust. Thus, if short-wavelength gravity features are neglected the Bouguer-anomaly map should reflect variations in crustal thickness.

Published crustal refraction and gravity interpretations (Shor et al. 1971; Woodward and Hunt, 1971) indicate that the Tasman Basin has a crust of oceanic thickness (10 km); the Dampier ridge has a crust of subcontinental thickness (23 km); the Lord Howe Basin has a crust of suboceanic thickness (10-17 km); and the Lord Howe Rise has a crust of continental thickness (28 km). Thus in Plate 9 areas with a Bouguer anomaly of less than +100 milligals can be considered to have a crust of continental thickness, and areas with a Bouguer anomaly of greater than +200 milligals can be considered to have a crust of oceanic thickness. Areas with Bouguer anomalies between +100 and +200 milligals, such as the Dampier Ridge and the Lord Howe and Middleton Basins, can be considered to have a crust intermediate between continental and oceanic thickness.

Other important features of the Bouguer-anomaly map are:

(1) the strong northwest-trending structural lineament that runs across the northern margin of the north Tasman Basin, Dampier Ridge, and Middleton Basin is reflected in the Bouguer-anomaly pattern

(2) the *en echelon* character of the eastern margin of the north Tasman Basin is reflected in the Bouguer-anomaly pattern.

Thus it appears that both of these large-scale features may be of crustal significance.

The results from one refraction station in the north Tasman Basin by Shor et al. (1971) indicate that the oceanic layer of the normal three-layer oceanic crust may be absent in this area; thus they suggest that the north Tasman Basin may have formed as a rift to the base of the crust, and then been filled with sediments or igneous extrusives. The absence of the oceanic layer is usually taken to indicate either that the oceanic crust was not formed by normal seafloor-spreading processes about a mid-oceanic ridge, or that the rate of spreading was extremely slow (Vogt et al., 1969).

RESIDUAL MAGNETIC ANOMALIES

Plate 10 is a residual magnetic-anomaly map relative to the International Geomagnetic Reference Field (IGRF). It shows the nebulous residual field, which generally consists of many short-wavelength positive closures superimposed on a broad, negative (-50 to -100 gamma) field. The main features apparent on the residual magnetic anomaly map are:

(1) a vague north-northeast trend on the abyssal plain

(2) a prominent northwest trend corresponding to the structural lineament across the northern margin of the north Tasman Basin and Dampier Ridge

(3) a broad, positive (50 to 100 gamma) anomaly over the Dampier Ridge.

About ten east-west, total-field magnetic profiles have been computer-plotted using 10-second data and none of these show any obvious correlation of anomalies from profile to profile, in the north Tasman Basin. Anomalies on the profiles can usually be related to the topography of the basement surface observed on the seismic sections.

REGIONAL STRUCTURE AND TECTONIC EVOLUTION

Plate 11 is a stylised regional structural map of the Tasman Sea indicating the major physiographic features such as ridges, offshore continental blocks, ocean basins, and trench systems. Some of the prominent structural trends in the Tasman Geosyncline are shown and an attempt has been made to extend these into offshore continental areas. Trends shown on the eastern margin of the north Tasman Basin are to indicate that the shape of this margin may have been controlled by Tasman Geosyncline-type structural lineaments.

The northeast trends which lie between the Townsville Trough in the north and the Tasman Basin and Lord Howe Rise in the south are based on the results of the BMR survey and the regional bathymetric map of Mammerickx et al. (1971). North of the northern end of Lord Howe Rise these trends enclose an area of linear features with rugged relief called the Mellish Rise (Cullen, 1970).

In Plate 11 the Tasman Basin has been subdivided into the three provinces used by Conolly (1969) i.e. the abyssal plain, the swale province, and the abyssal hills province. The approximate position of the northwest-trending basement ridge in the central Tasman Basin, as described by Ringis (1970) and Hayes and Ringis (1972), is also shown. Hayes and Ringis (1972) suggest that the ridge is an extinct spreading centre that was responsible for the opening of the central Tasman Basin from 80 m.y.B.P. to 60 m.y.B.P.

Using the regional structural map a tentative tectonic evolution of the Tasman Sea area can be proposed. Before Upper Cretaceous time the Lord Howe Rise may have existed as a trough-bounded marginal plateau off the eastern margin of the Australian continent. This would explain the late Maestrichtian biogenic ooze encountered in deep-sea drill holes 207 and 208 of leg 27 of the Deep Sea Drilling Project (1972). About 80 m.y.B.P. rotational spreading commenced in the central Tasman Sea, about a centre of

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rotation in the Gulf of Papua area. This initiated a rift zone in the north Tasman Sea, with some separation of Australia and Lord Howe Rise. During the rotational spreading the northern margin of Lord Howe Rise moved northeast with respect to Australia along the lineament forming the southern border of the Mellish Rise. The Dampier Ridge probably formed as an intrusive complex or volcanic ridge in the narrow rift between Australia and Lord Howe Rise in the north Tasman Sea.

Further opening of the Tasman Basin as a result of the northeast movement of the Lord Howe Rise and Dampier Ridge block along the southern margin of the Mellish Rise occurred possibly either as an increase in the rate of spreading about a centre in the central Tasman Basin or as rifting between Australia and the western margin of the new oceanic crust.

According to the latter hypothesis the abyssal plain in the north Tasman Basin was a rift zone, and the shape of the basin in this area was controlled by the northeast movement of the Dampier Ridge/Lord Howe Rise block and structural trends similar to those of the Tasman Geosyncline. This second stage of separation is necessary in order to explain the present asymmetric position of the Dampier Ridge between Lord Howe Rise and Australia. The Mellish Rise probably formed as the result of igneous activity in a zone of transcurrent displacement caused by the relative northeast motion of Lord Howe Rise.

A rotational spreading environment about a centre of rotation in the Gulf of Papua area can also explain the opening of the Coral Sea Basin and possibly the Solomon Sea.

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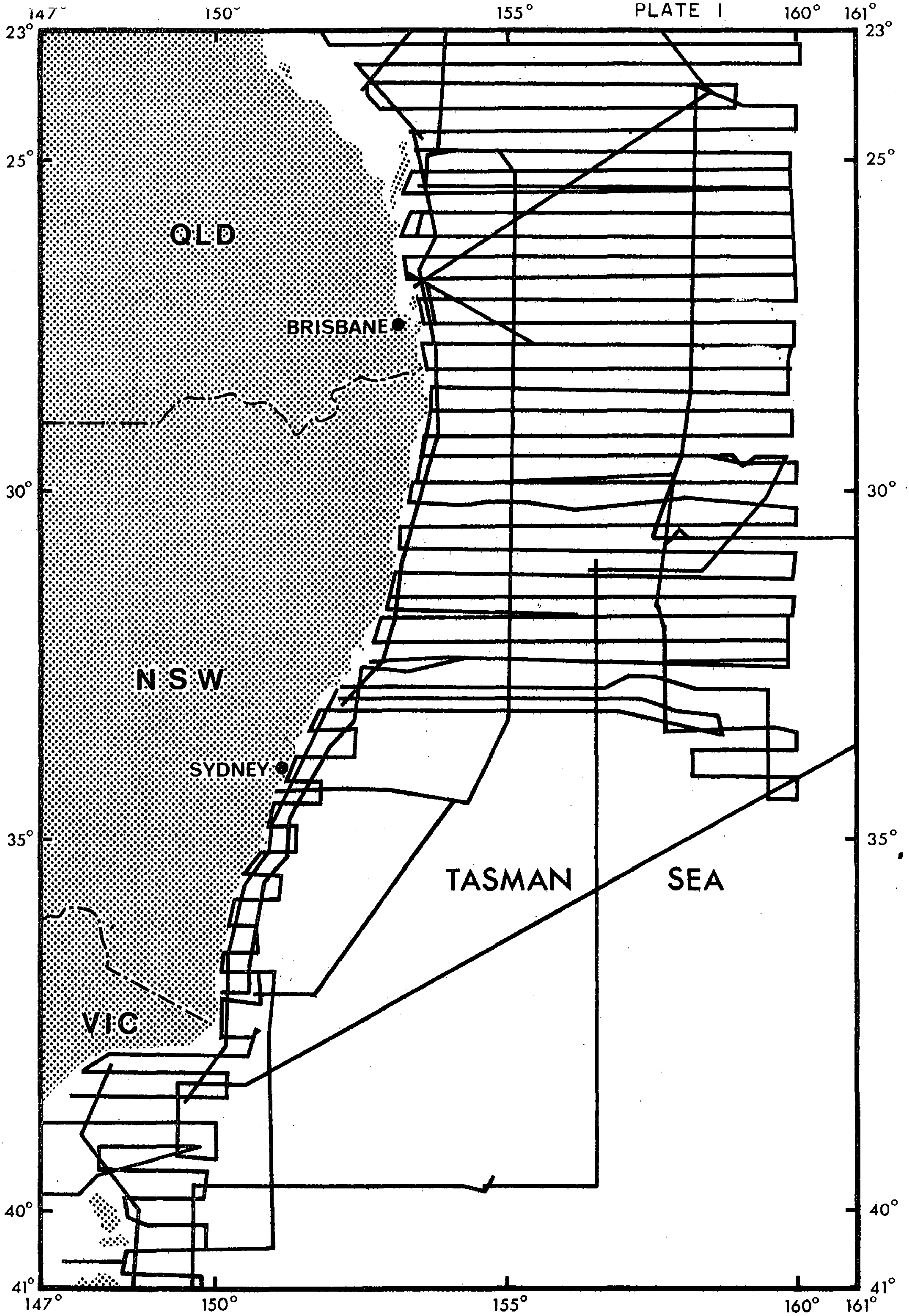
PLATE I



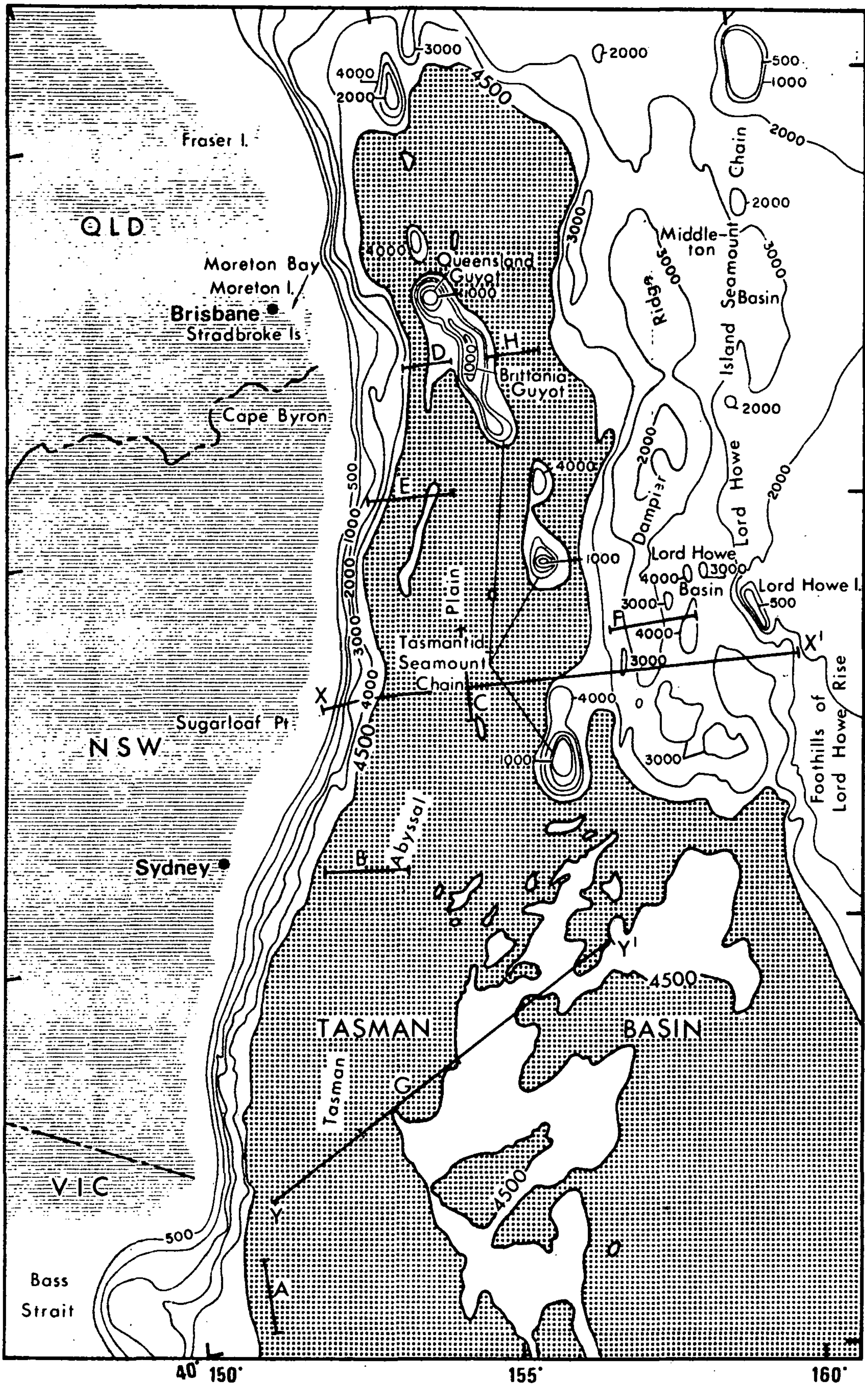
THE STRUCTURE OF NORTH TASMAN SEA

TRAVERSE PLAN

A/B8-18A 13

accompany Record No 1973/167

PLATE 2



BATHYMETRY

100 0 100 300 500 700 Km

A Seismic section line

2000 Isobath (metres)

14

To accompany Record No 1973/167

A/B8-19A

SCHEMATIC PROFILES

To accompany Record No 1973/167

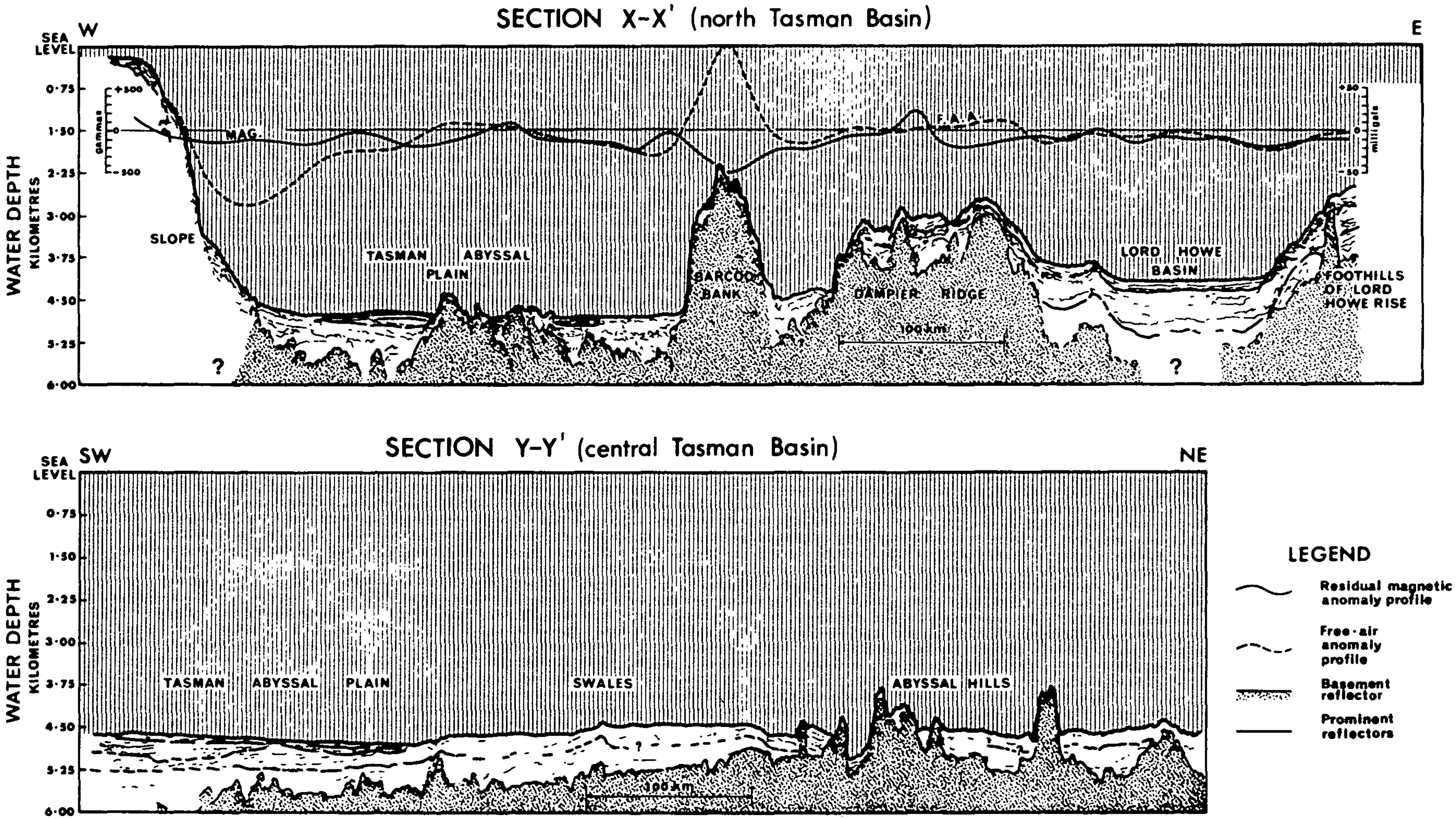
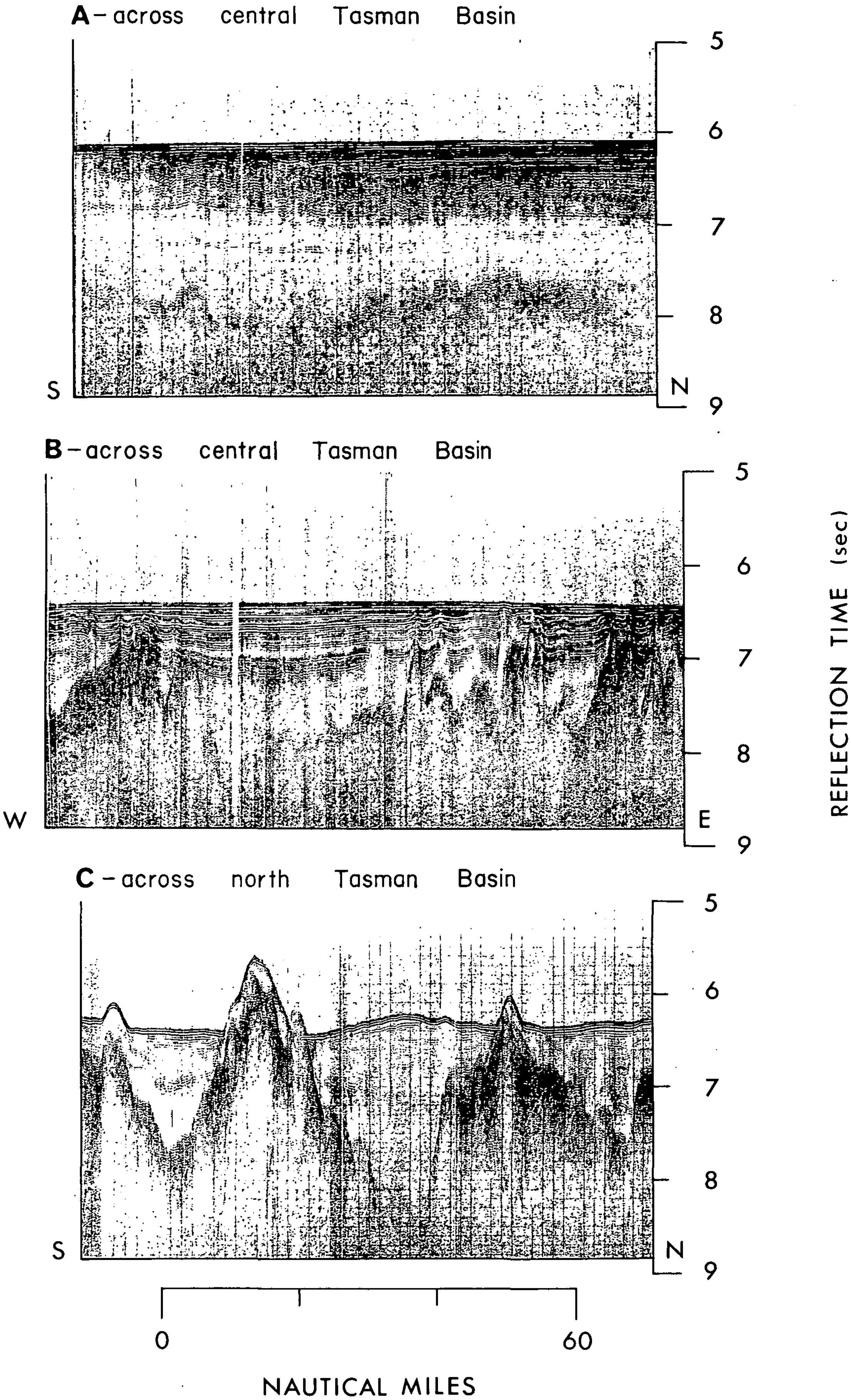


PLATE 3

A/B8-20A

PLATE 4



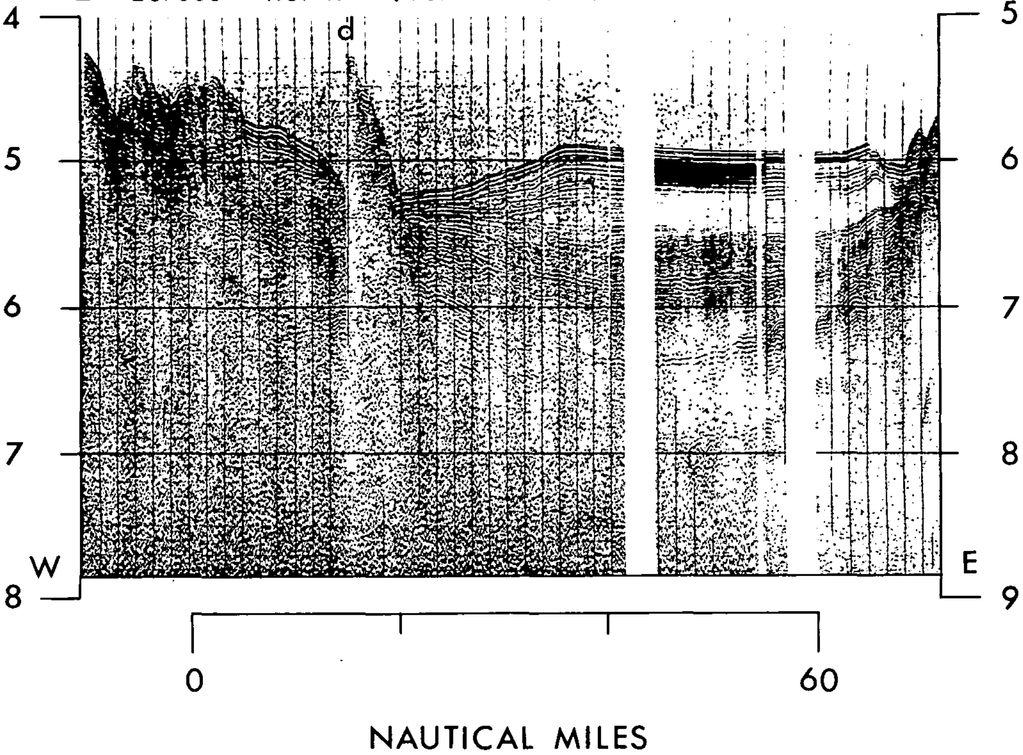
SEISMIC SECTIONS A, B and C

16

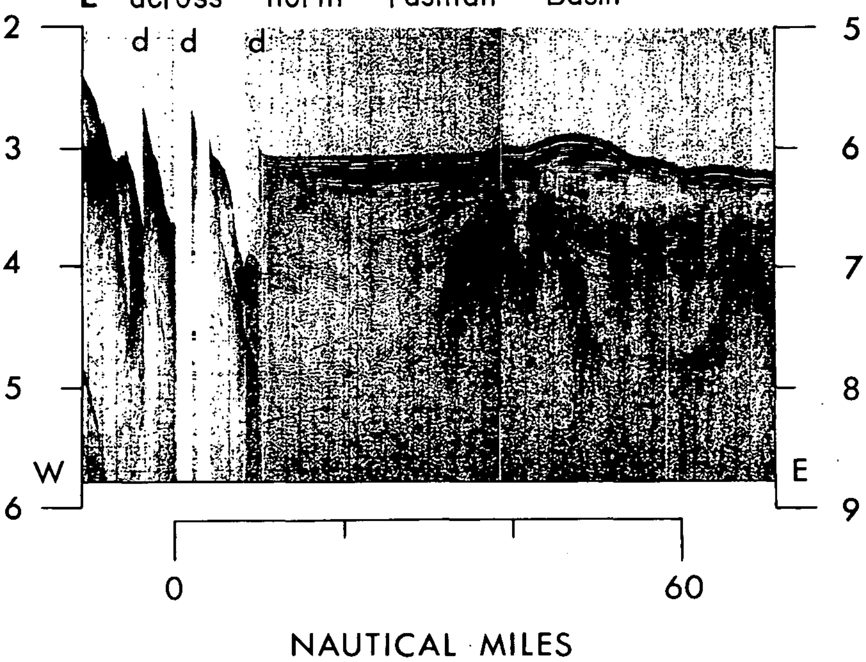
To accompany Record No 1973/167

A/B8-25A

D - across north Tasman Basin



E - across north Tasman Basin



REFLECTION TIME (sec)

d - Recording delayed by one second

SEISMIC SECTIONS D and E

17

A/B8-26A

To accompany Record No 1973/167

To accompany Record No 1973/167

SEISMIC SECTION F

F - across Dampier Ridge

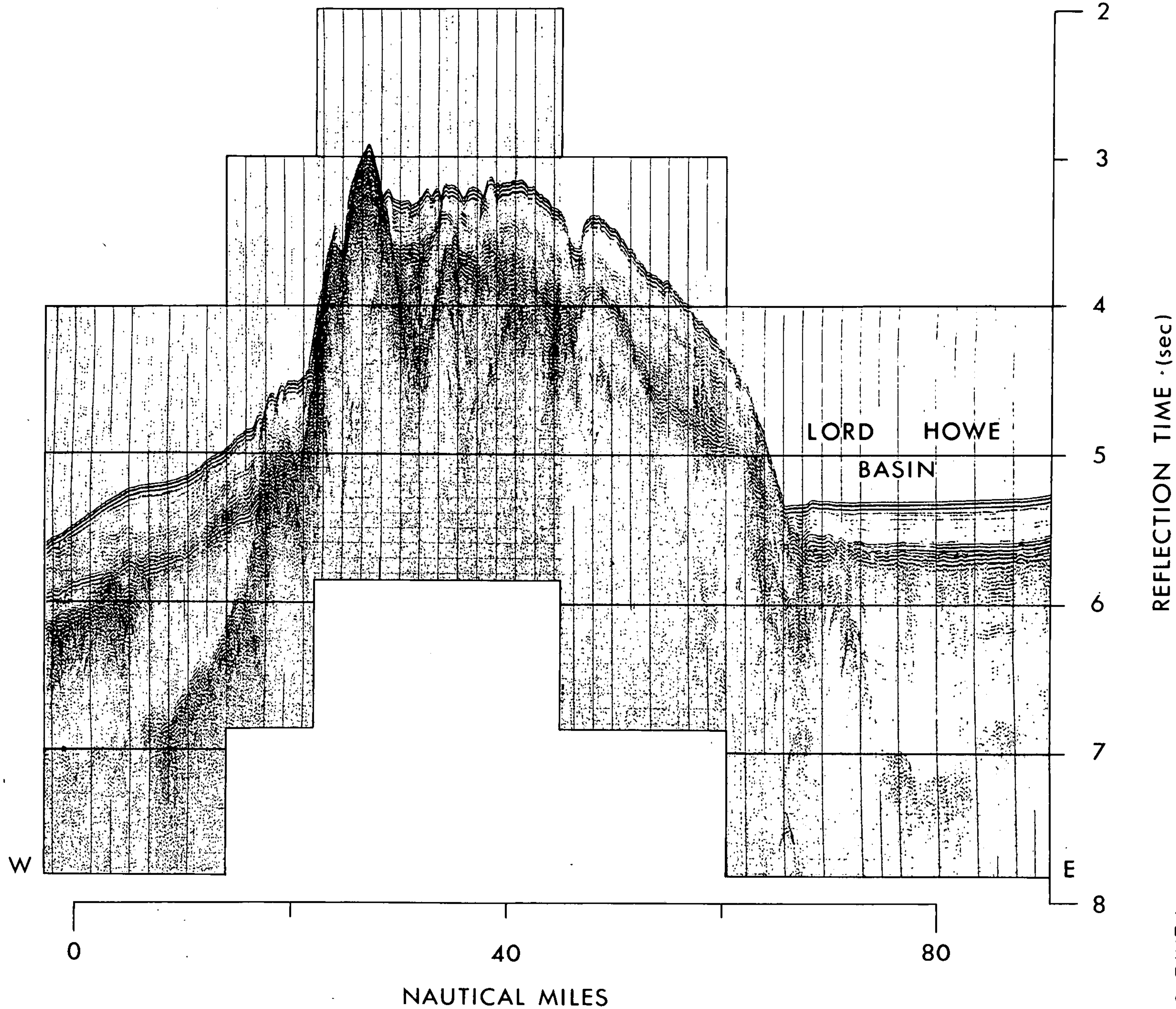


PLATE 6

A/B8-27A

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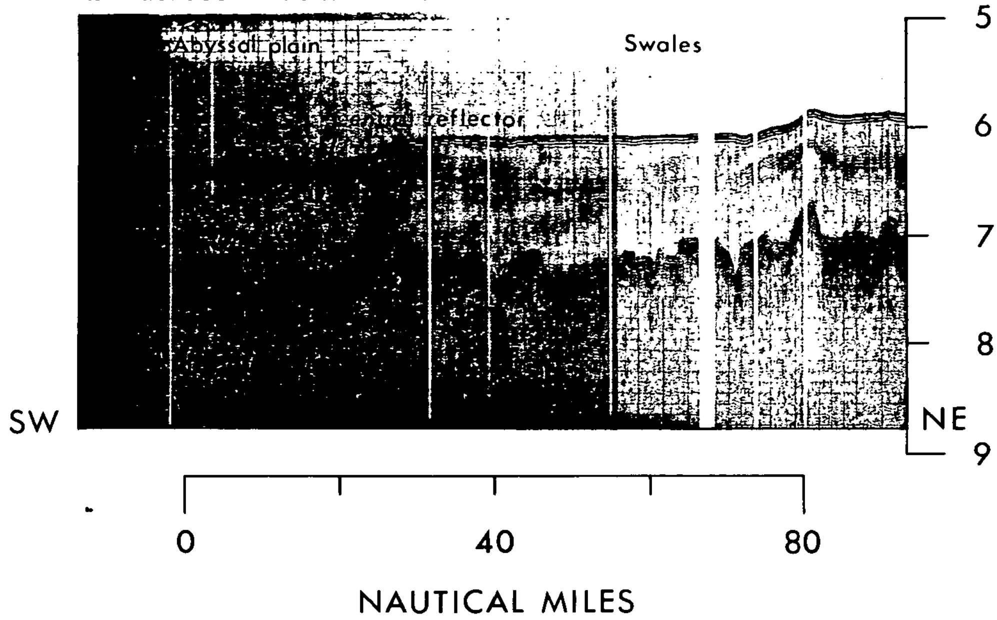
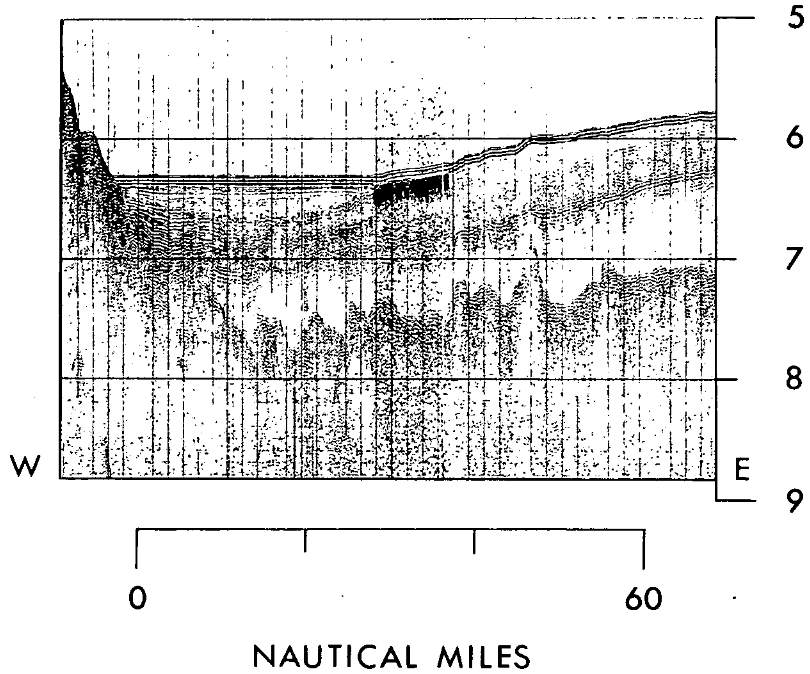
G – across central Tasman Basin



REFLECTION TIME (sec)

H – across north Tasman Basin



SEISMIC SECTIONS G and H

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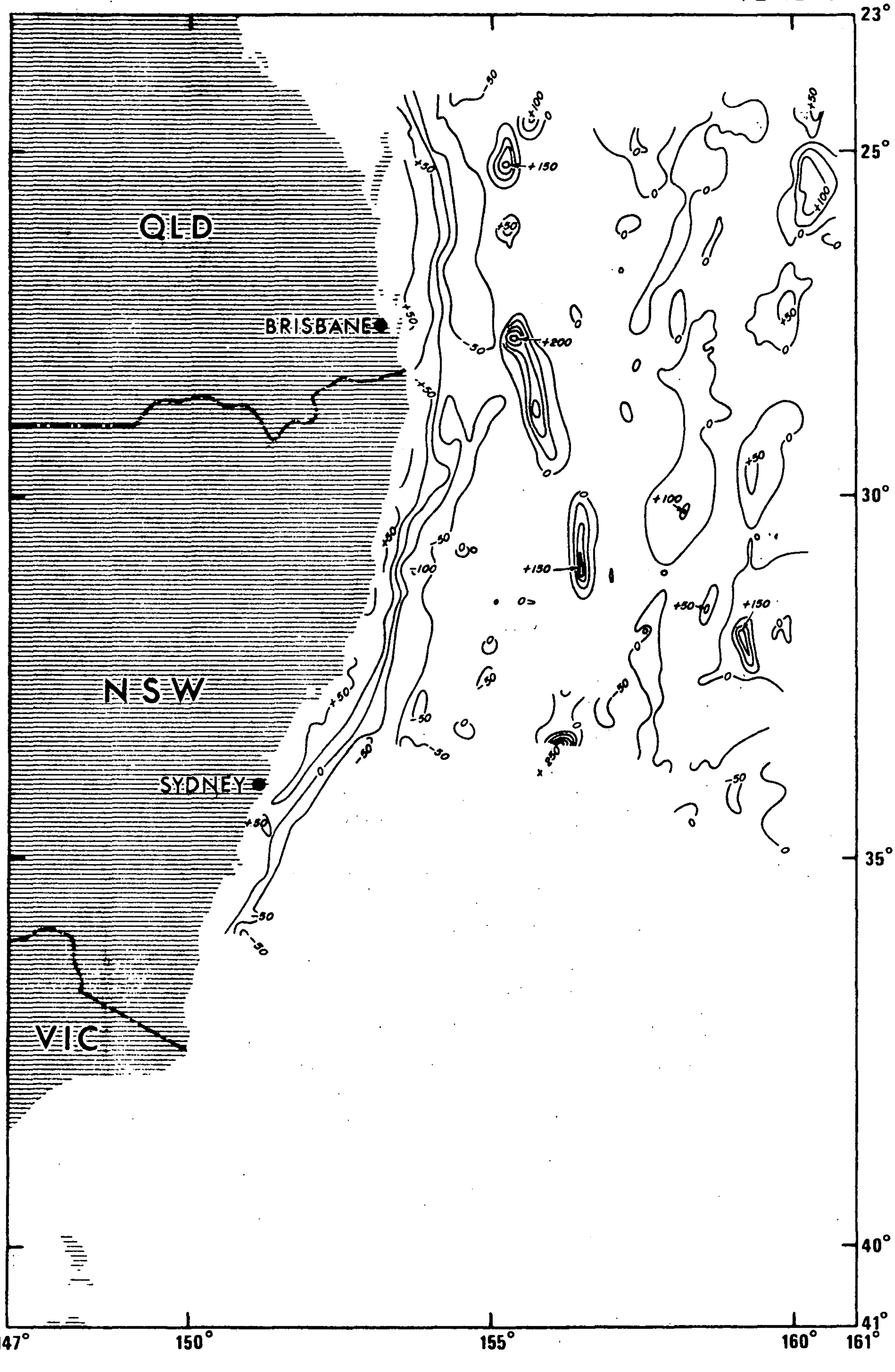
To accompany Record No 1973/167

A/B8-28A

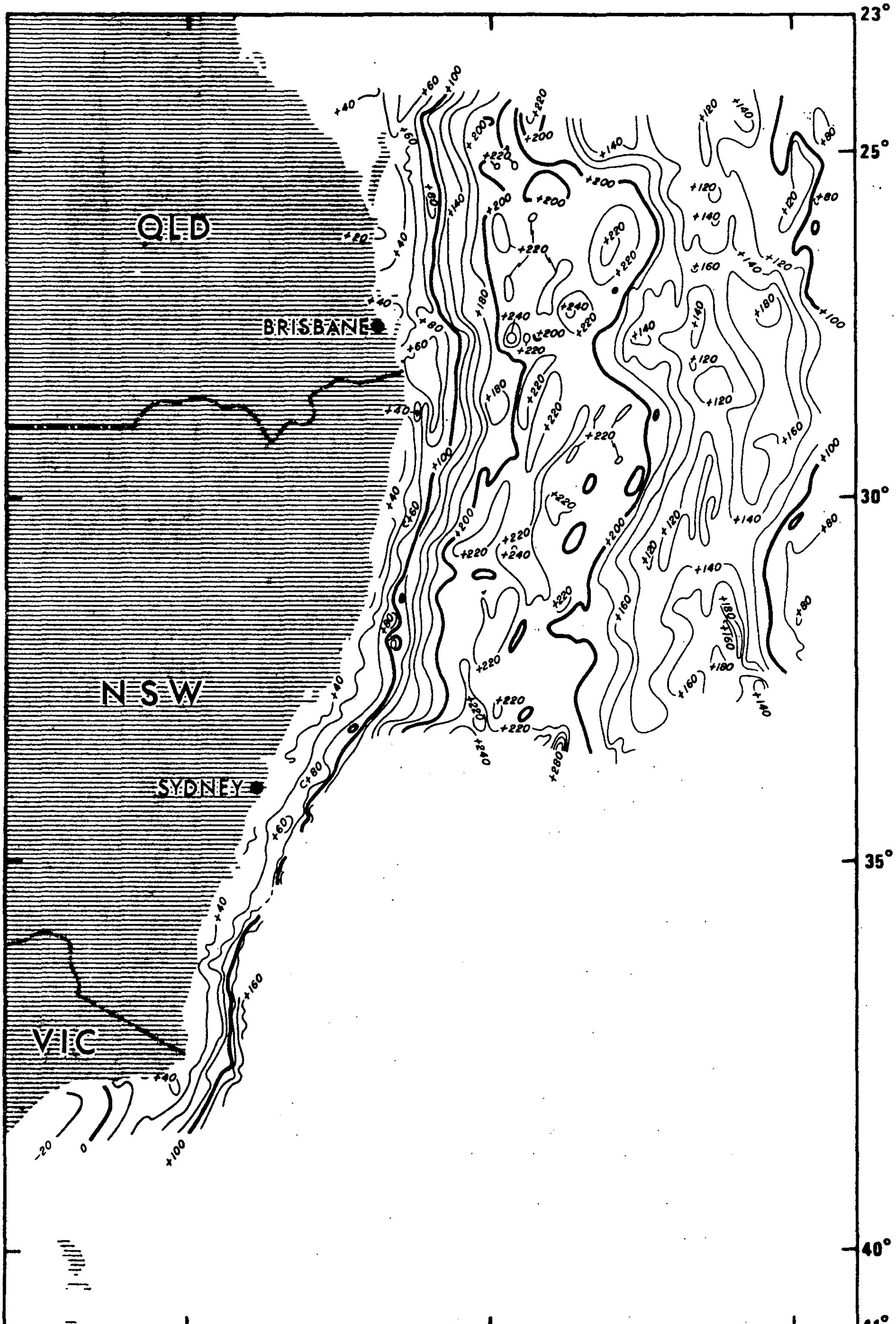


FREE-AIR ANOMALIES

20

ccompany Record No 1973/167

A/B8-23 A

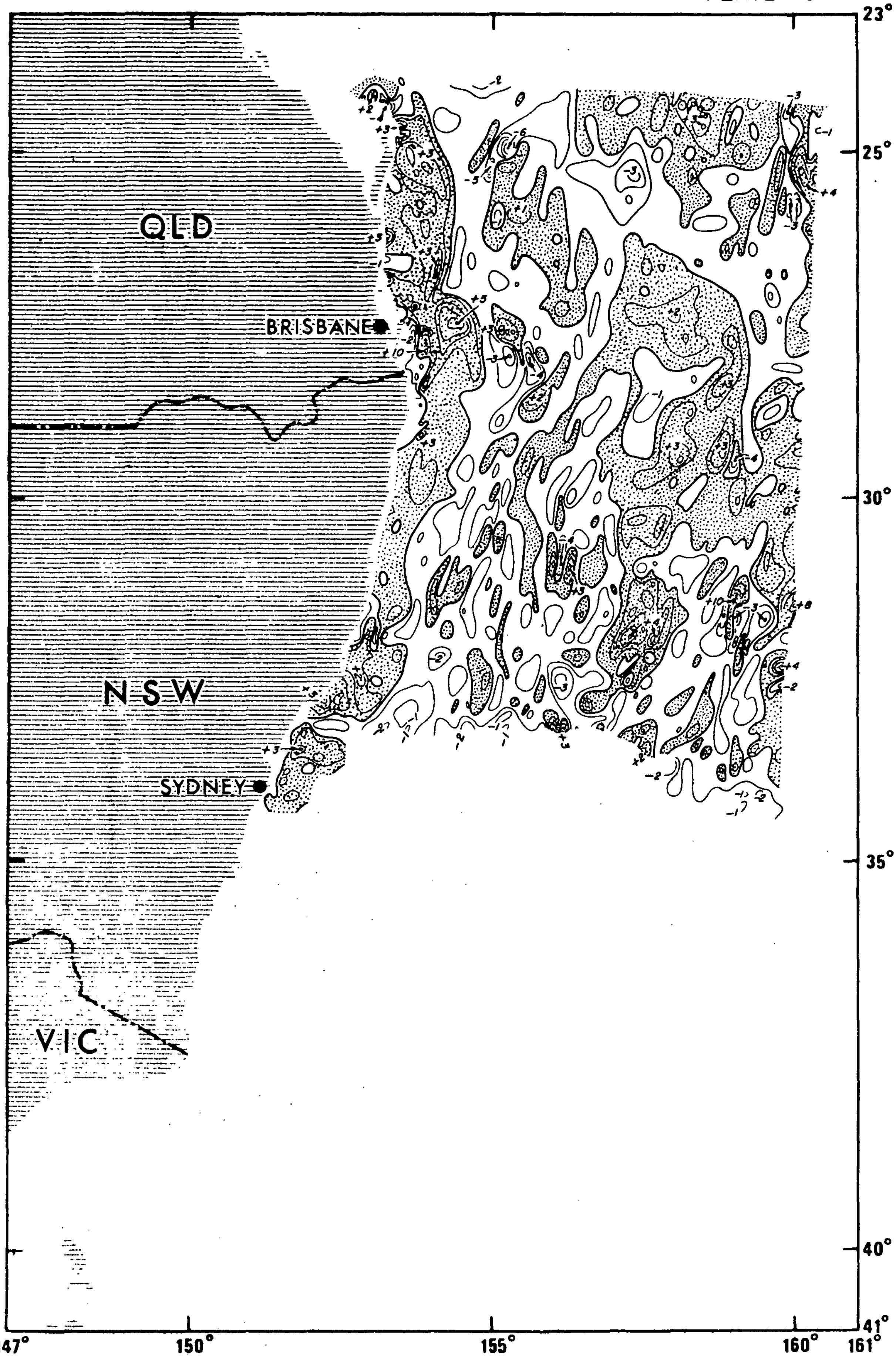


+200 Isogal (milligals)

BOUGUER ANOMALIES

100 0 100 200 300 400 KILOMETRES

2/



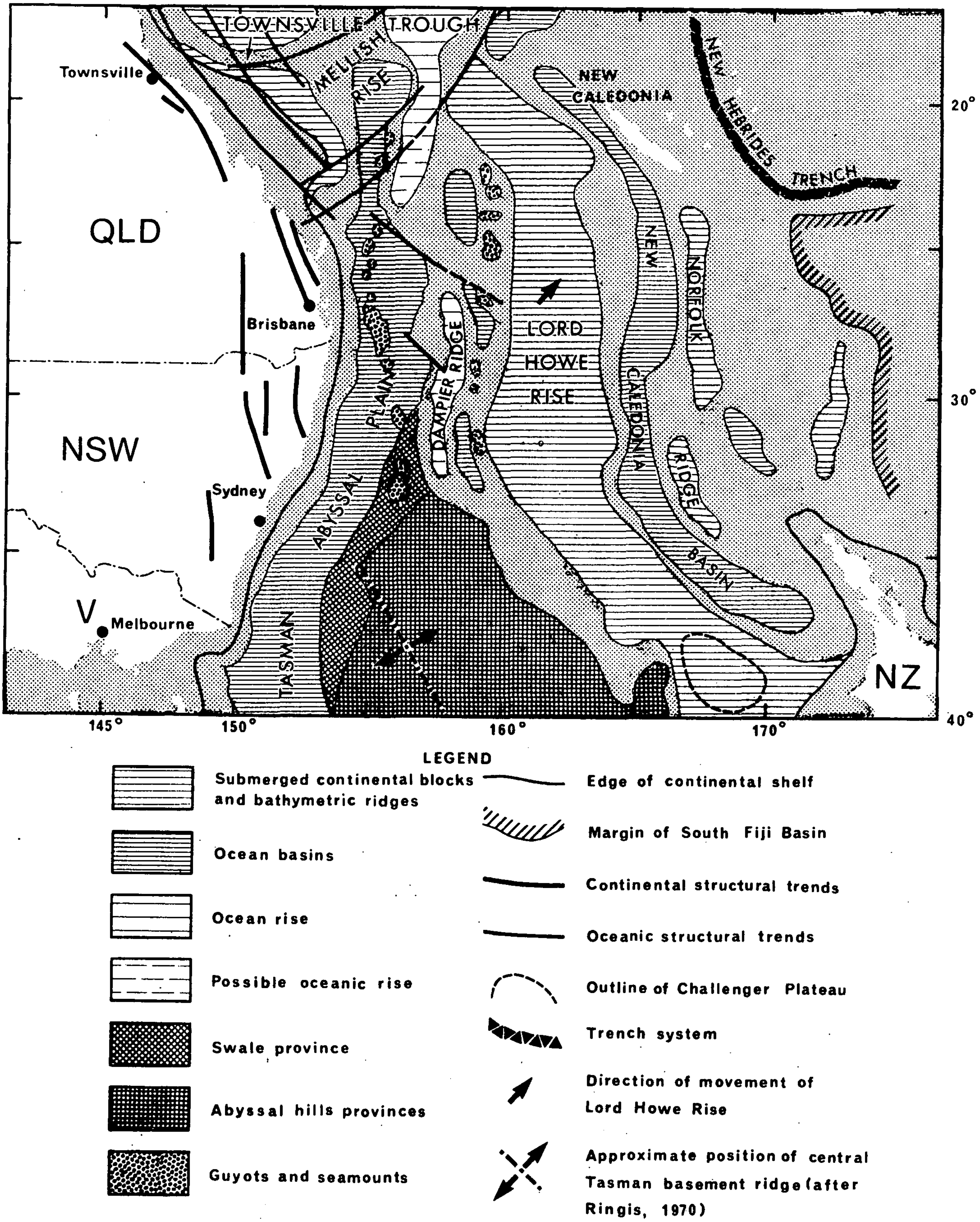
MAGNETIC CONTOURS

Stipple indicates positive values

-3 Denotes minus 300 Gamma

100 0 100 200 300 400 KILOMETRES

22



STYLISED REGIONAL STRUCTURES

SCALE

200 0 200 400 600 800 1000 KILOMETRES

Scale between 20°–25° South

23

To accompany Record No 1973/167

A/B8-24A