DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

~~CONFIDENTIAL~~

Record 1976/10

SEABED MARGINS AND RESOURCES POTENTIAL OF MACQUARIE RIDGE, NORFOLK RIDGE AND LORD HOWE RISE

by

J. Pinchin, D. Jongsma and J.J. Petkovic

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PLATES IN ENVELOPE AT BACK

SUMMARY

Macquarie Island, Lord Howe Island and Norfolk Island lie on three northerly-trending submarine ridges. Macquarie Ridge is a long, narrow, steep-sided complex formed mainly of upthrust oceanic crust. Lord Howe Rise and Norfolk Ridge are both probably submerged bands of continental crust split off from the eastern margin of Australia by sea-floor spreading some 80 m.y. ago. Both Lord Howe Rise and Norfolk Ridge are broader and less rugged than Macquarie Ridge. None of the three ridges are flanked by a true continental slope or rise as all three have been below or near sea-level since their formation and have not shed the sediments necessary to form such features.

Because all three ridges adjoin the New Zealand continental margin, the selection of a geological or morphological boundary is difficult. Tentative boundaries have been drawn on the accompanying maps. Macquarie Ridge merges with the New Zealand margin at about 47°S. Bellona Gap at 37°S separates Lord Howe Rise from New Zealand and a similar topographic saddle at 36°S separates Norfolk Ridge from New Zealand. All three ridges lie in an area of complex plate tectonics and much more geophysical and geological investigation will be required before the geology is understood.

The economic mineral potential of all three ridges appears very low. There is little chance of economic petroleum resources on Macquarie Ridge. Lord Howe Rise and Norfolk Ridge both contain small sedimentary basins that could hold petroleum reservoirs but the deep water and remoteness of the area would make any oil exploration and production venture extremely expensive. Further marine geophysical reconnaissance surveys are recommended over Lord Howe Rise and Norfolk Ridge to assess properly their petroleum potential.

MACQUARIE RIDGE

Morphology

The Macquarie Ridge is a ridge complex which extends from the continental shelf of New Zealand southwards through Macquarie Island (Pl. 1 and Fig. 1). The Ridge is bisected in three places by major deep-water passages, two of which lie between Macquarie Island and New Zealand. These passages mark major structural offsets of the Ridge.

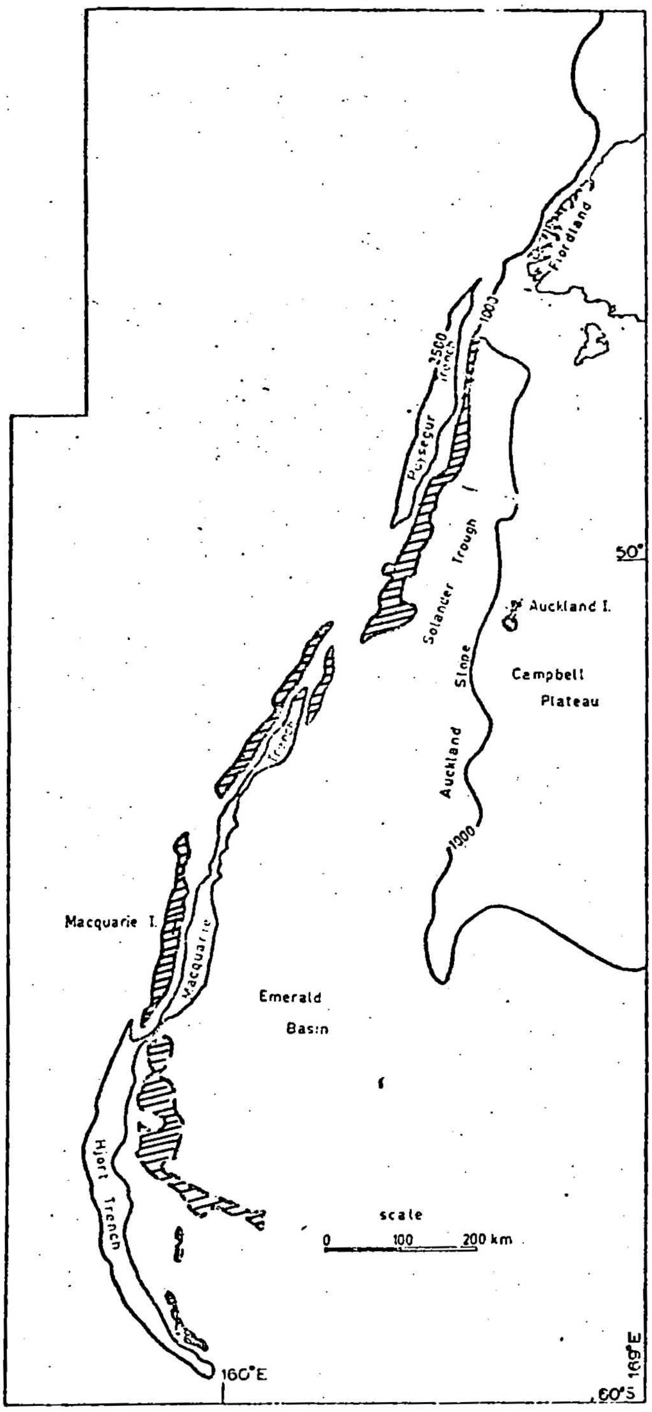
The bathymetric map (Pl. 1) and the seismic profiles across the Ridge (Figs. 2 to 5) show that it is a long, narrow, steep-sided structure. Both east and west flanks of the Ridge drop at about 20° to the ocean basins on either side. The Ridge rises abruptly from the sea-floor, and this abrupt change of slope has been taken as the outer margin. Because of the rugged topography it is difficult to draw an exact outline for the Ridge margin; however a line marking the approximate position of the base of the Ridge is shown in Plate 2. It should be noted that the Ridge is not margined by a true continental slope or continental rise.

The Campbell Plateau, south of New Zealand, is bordered by a continental slope which, along parts of the western margin of the Plateau, appears to be steep and faulted (Fig. 6a). However, one profile across the southern margin of the Plateau shows what may be a small continental rise (Fig. 6b). More bathymetric profiles are needed to accurately determine the limits of the Plateau margin. In Plate 2 a line drawn along the base of the slope, or rise where it exists, shows the possible limits of the margin.

Geological evolution

The plate tectonics of the Macquarie Ridge area is very complex and only partly understood. One possible geological history is discussed briefly here. In BMR Record 1976/12, D. Jongsma discusses this complex subject in more detail, and gives numerous references.

It seems likely that oceanic crust was generated by sea-floor spreading during the period between 10 and 38 m.y. ago (early Miocene). Convergent plate motions after 10 m.y. ago caused crustal compression, thrust faulting, and transform faulting. The ocean-floor was uplifted, probably in the Pliocene (3 to 7 m.y. B.P.), to form Macquarie Ridge and Macquarie Island. Thus the island and ridge were formed of uplifted basaltic ocean-



.. Morphology of the vicinity of the Macquarie Ridge. The Ridge and Campbell Plateau are defined by the 1000 fm contour (solid) and 1500 fm contour (dashed). The trenches are defined by the 2500 fm contour. Macquarie Ridge is shaded. Generalised from Hayes and Talwani (1972).

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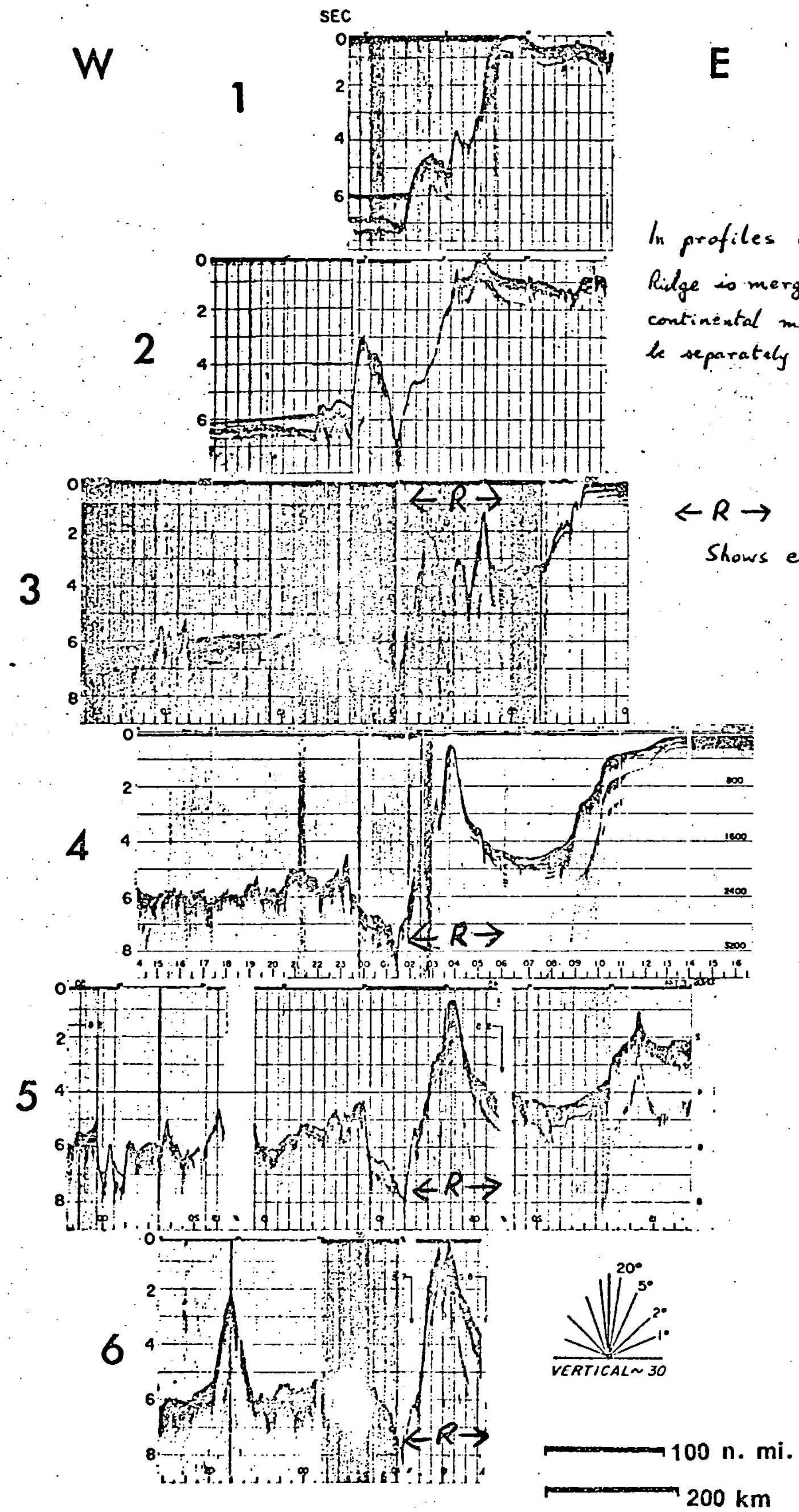
Figure 1.



In profiles 1 and 2, Macquarie Ridge is merged with New Zealand continental margin and cannot be separately distinguished.

← R → Shows extent of Macquarie Ridge

Representative seismic profiler traverses across the northern section (Puysegur trench region) of the Macquarie ridge. Profiles are aligned along the ridge. One second of reflection time is approximately equal to 1 km of sediment.

(From Hayes & Talwani, 1972)

Figure 2

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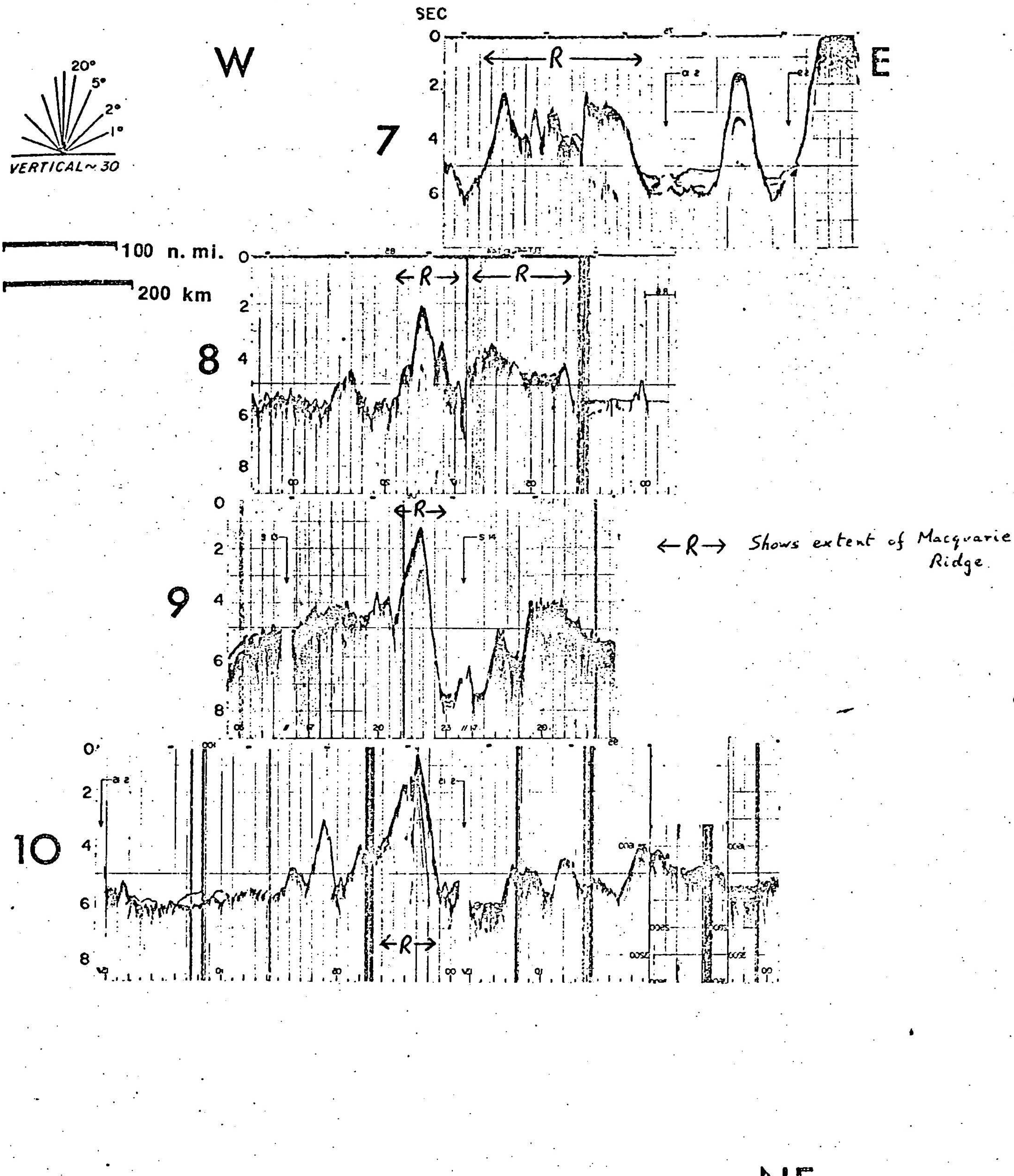
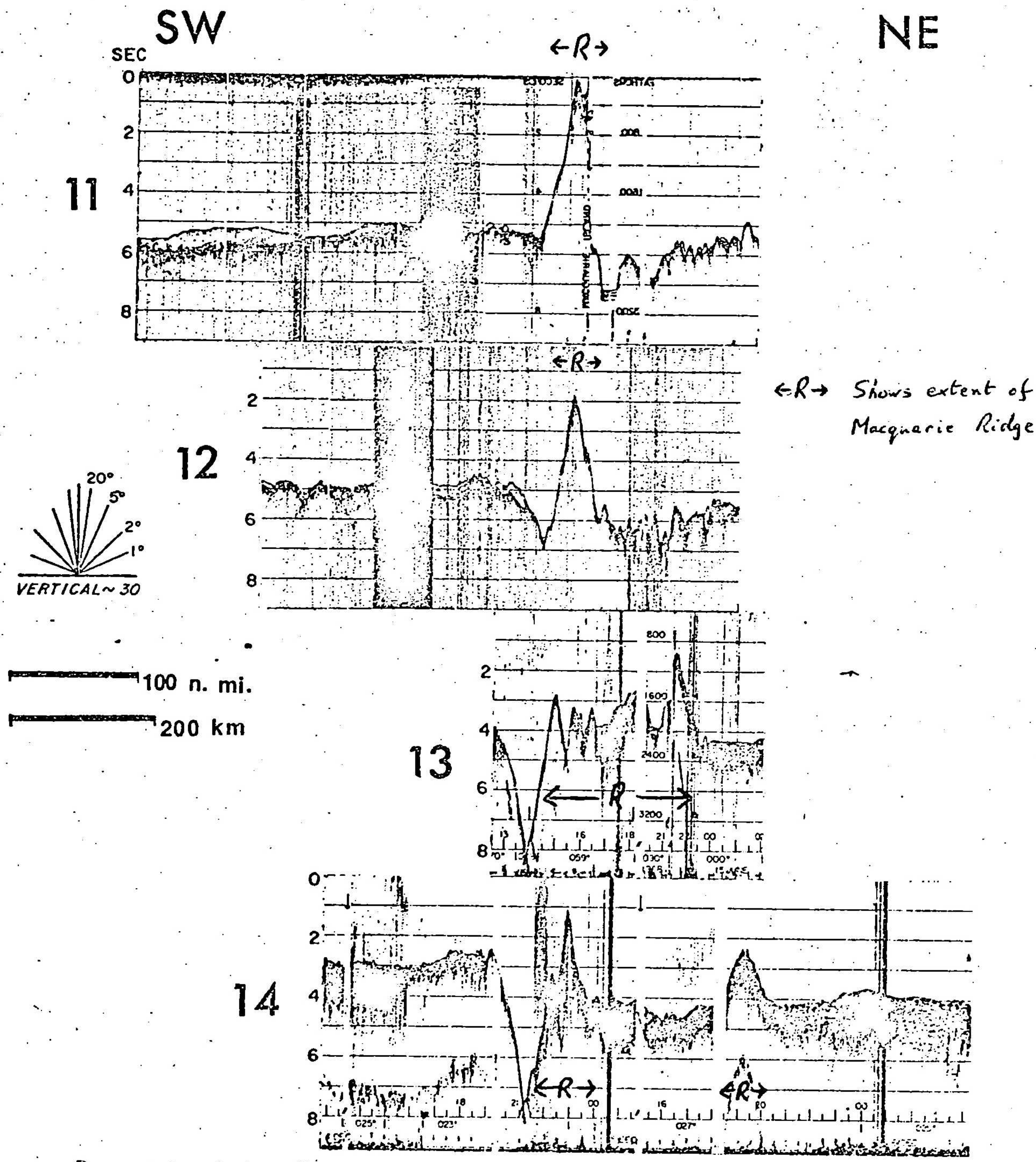


Representative seismic profiler traverses across the central section of the Macquarie ridge. Profiles are aligned along the ridge. One second of reflection time is approximately equal to 1 km of sediment.

(From Hayes & Talwani, 1972)

Record N° 1976/10

Figure 3



Representative seismic profiler traverses across the southern section (Hjort trench region) of the Macquarie ridge. Profiles are aligned along the ridge. One second of reflection time is approximately equal to 1 km of sediment.

(From Hayes & Talwani, 1972)

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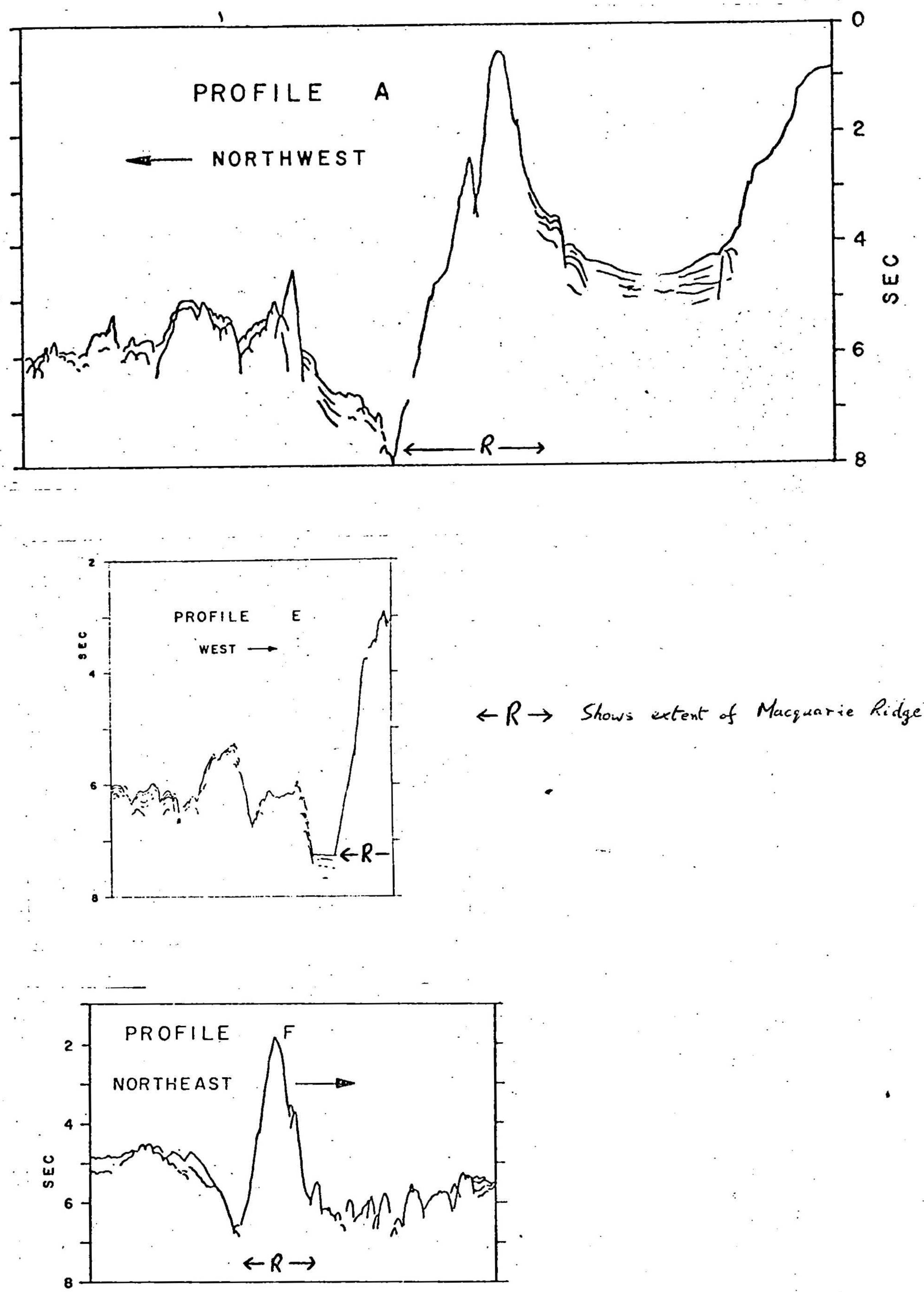
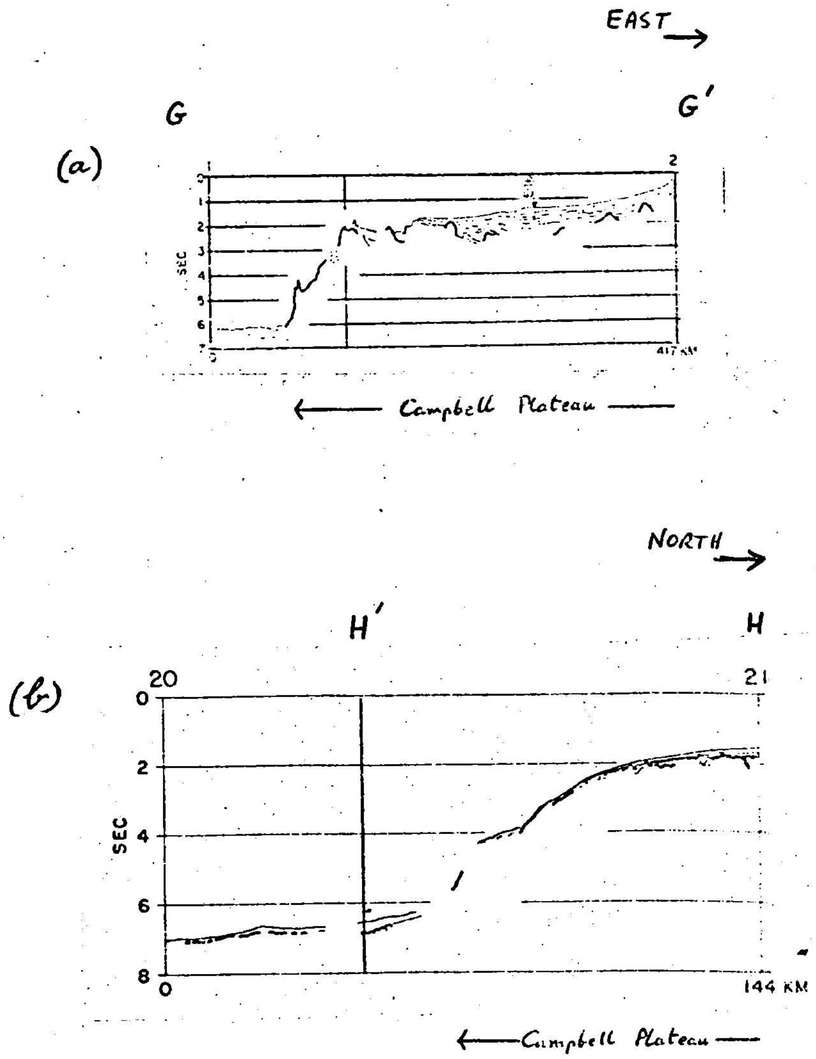
Figure 4



Profiler sections of the Macquarie Ridge. Vertical exaggeration about 30:1. (From Houtz, Ewing, & Embley, 1971)



Conrad (upper) and Eltanin (lower) profiler sections of Campbell Plateau

(From Houtz, Ewing, Ewing, & Lonardi, 1967)

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Figure 6

floor which was subsequently intruded by ultramafic rocks from deeper within the crust (see Fig. 7). One possible pattern of plate motions is that deduced by Molnar et al. (1975) and shown in Figures 13 to 15.

Resources potential

The economic mineral and petroleum potential of Macquarie Island and Macquarie Ridge is virtually nil. No mineralization has been recorded on the island and current geological theories are not in favour of mineralization in this type of tectonic setting. The nature and sparsity of sediments on the ridge also excludes the possibility of any significant hydrocarbon accumulation. Although a basin east of the southern ridge contains about 1000 m of sediment, their young age and nature (pelagic oozes) makes them unprospective.

Manganese nodules have been photographed on the seafloor of the ridge; they occur in a wide belt around Antarctica. However the nodules appear to be depleted in valuable metals such as nickel, copper, and cobalt when compared to those of the North Pacific and they can be regarded as being of sub-marginal prospectivity.

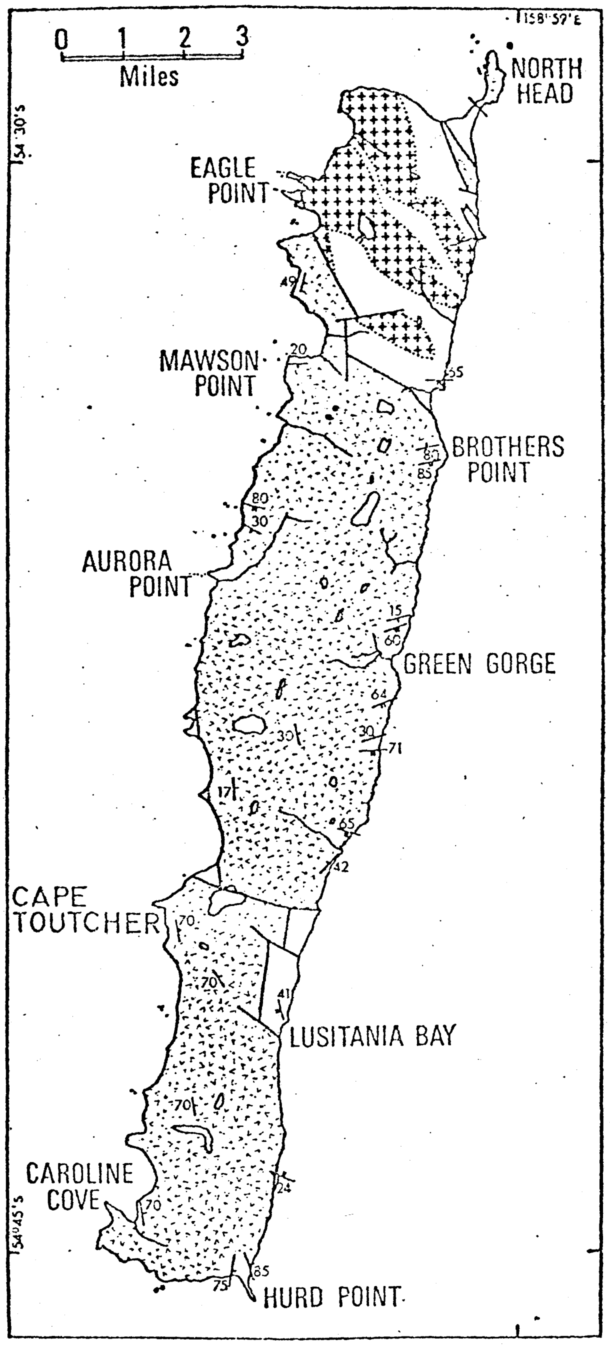
LORD HOWE RISE AND NORFLOK RIDGE

Morphology of Lord Howe Rise

Lord Howe Rise is a northwest-trending submarine structure that extends from the eastern side of the Coral Sea to New Zealand (Fig. 8). It is about 1600 km long and 250 to 500 km wide. Its northern end is marked by Lansdowne Bank near latitude 21°S, and at its southern end the 2000-m-deep Bellona Gap separates the Rise from Challenger Plateau. To the west of the Rise lies the Tasman Basin, and to the east lies the New Caledonia Basin.

Most of the Rise lies in water depths of 1000 to 2000 m, the crestal depths ranging from 750 to 1200 m. Lord Howe Island and Balls Pyramid lie near the south end of a north-trending chain of volcanic seamounts that flanks the western side of the Rise.

The bathymetric map (Pl. 3) and the seismic profiles (Figs. 9a, 9b; locations on Pl. 4) show that the main body of the Rise is characterized by gentle relief although much of the western side consists of a zone of more rugged 'foothills' (Figs. 9b, 9c). The junction of the foothills with the Tasman Basin is generally abrupt and the western extent of Lord Howe Rise can be easily mapped (Pl. 4).



Generalized geologic map of Macquarie Island with superficial deposits omitted. Serpentinized peridotite and gabbro masses are marked by crosses; extrusive volcanic rocks and associated sediments are marked by vees; dyke swarms are blank. Strikes on lavas are shown with a single tick, and strikes on dykes are shown with a double tick. Faulted contacts are drawn as heavy lines, and gradational or uncertain contacts are drawn as dotted lines.

Fig. 7 (After Varne & Rubenach, 1972)

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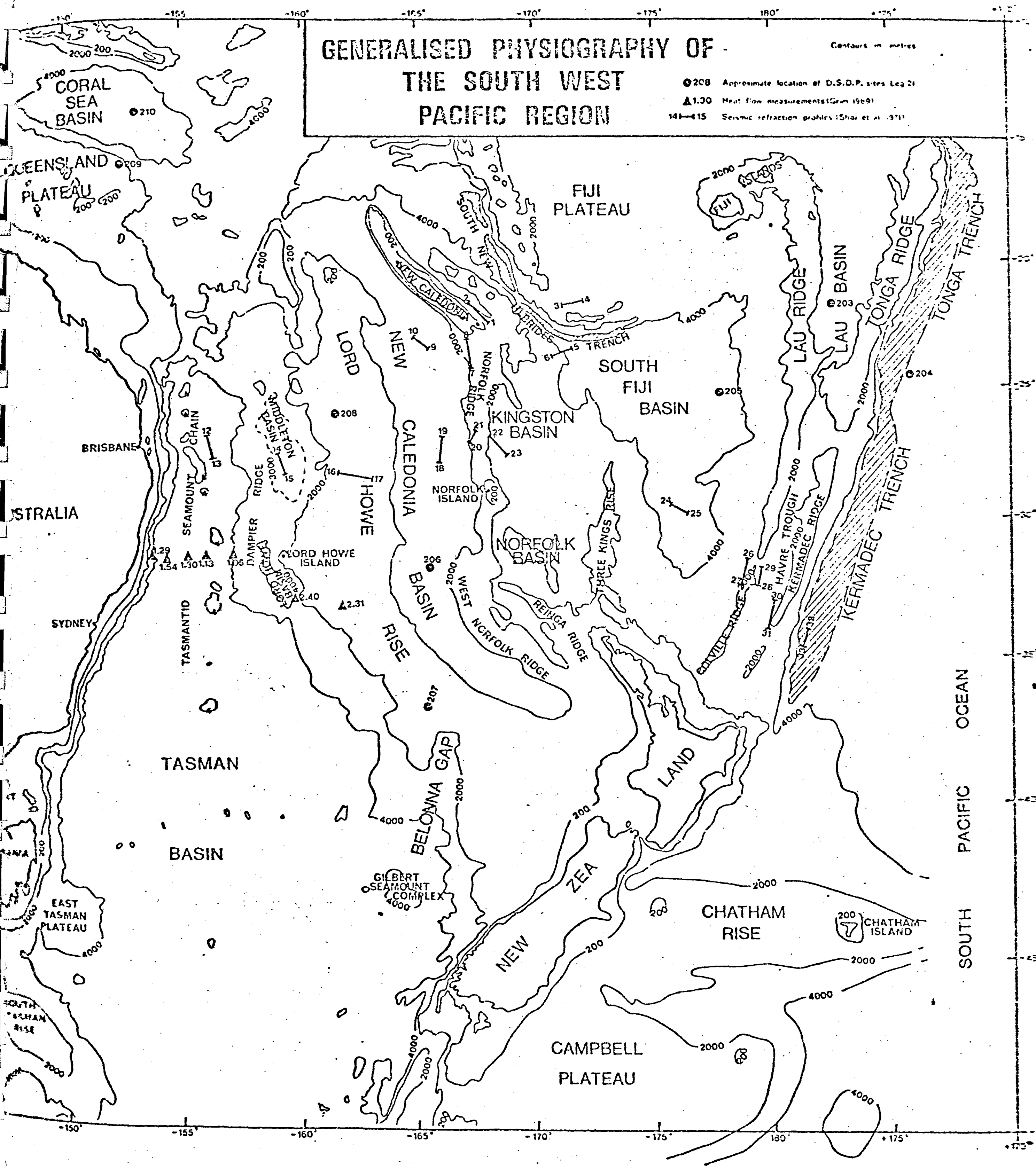
Figure 7



(From Ringis, 1972)

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Figure 8.

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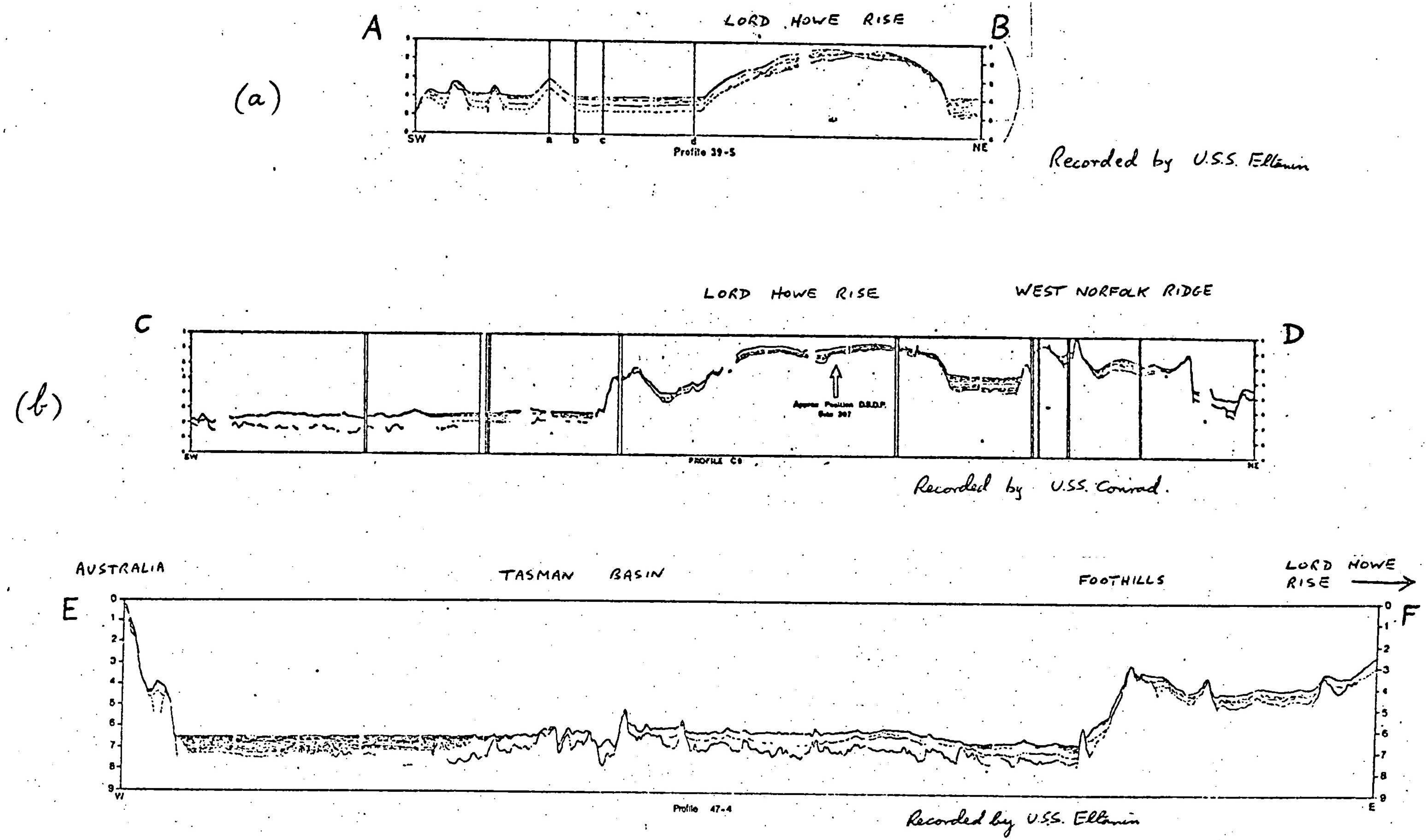


(From Ringis, 1972) SEISMIC PROFILER SECTIONS ACROSS LORD HOWE RISE AND NORFOLK RIDGE

Figure 9

The eastern slope of the Rise adjacent to the New Caledonia Basin is smoothly convex so that this boundary between the Rise and the Basin is also quite distinct (Figs. 9a, 10, 11; Pl. 4).

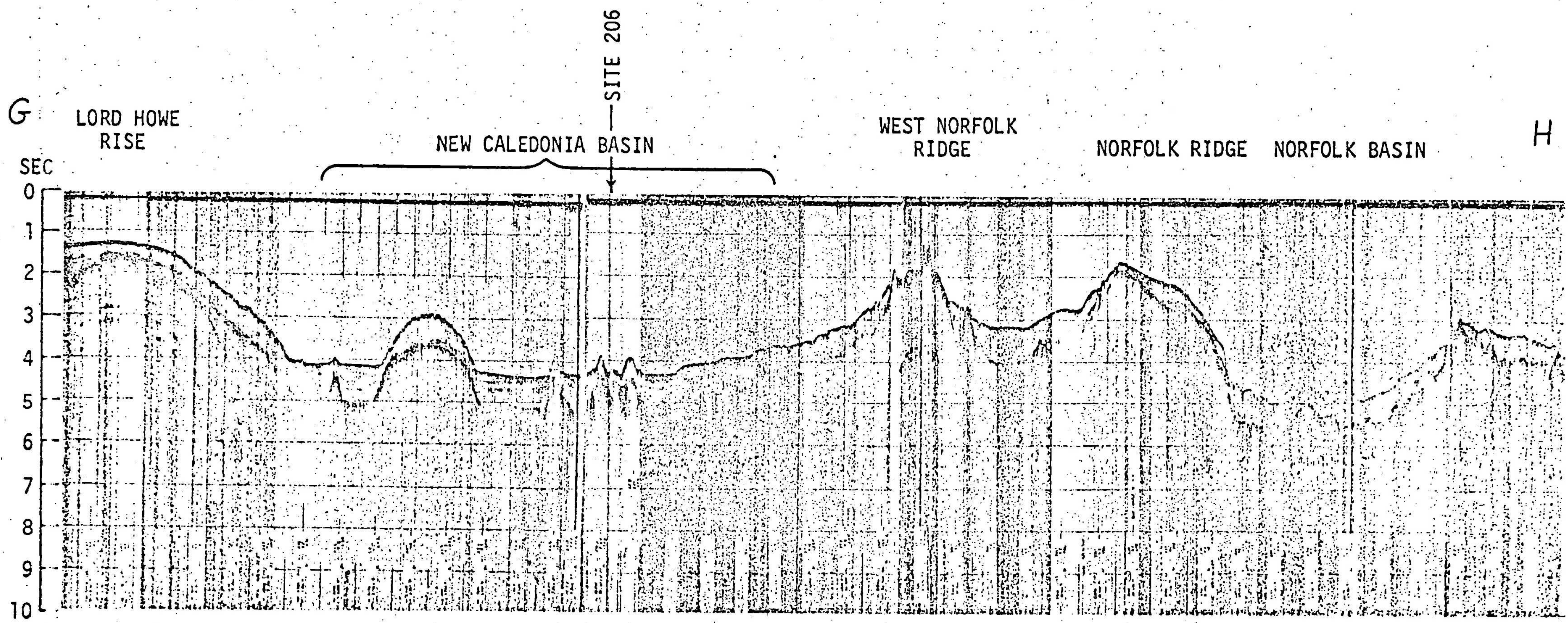
Lord Howe Rise was probably once part of the same continental block as New Zealand, and using physiography alone it is difficult to draw a definite boundary between them. Reconstruction of the evolution of this area (Molnar et al., 1975) indicates relative rotational movement of Australia, New Zealand, and Lord Howe Rise; Bellona Gap (Fig. 12) is likely to be a morphological break caused by this rotation of the crust. Thus in Plate 4 the boundary between Lord Howe Rise and Challenger Plateau has been drawn through Bellona Gap. It should be noted that the boundary outlines shown in Plate 4 are tentative and extensive geophysical surveying will be required before the crustal and geological structure of this area is known for certain.

Morphology of Norfolk Ridge

Norfolk Ridge lies parallel to, and about 450 km east of, Lord Howe Rise. The Ridge extends between New Caledonia and New Zealand (Fig. 8) and is about 1600 km long and 75 km wide. The New Caledonia Basin separates Norfolk Ridge from Lord Howe Rise, and Norfolk Basin lies to the east of Norfolk Ridge. The southern part of the Ridge is offset to the west by the Vening-Meinesz Fracture Zone and is called West Norfolk Ridge.

Norfolk Ridge is both narrower and more rugged than Lord Howe Rise. Seismic reflection profiles across the Ridge (Figs. 9b and 10) illustrate the comparatively rugged surface and steep east and west flanks of Norfolk Ridge. Norfolk Ridge and Lord Howe Rise are of much the same water depth but owing to this greater relief, Norfolk Ridge contains several areas shallower than 1000 m. Norfolk Island, Wanganella Bank, and the nearby Phillip Island are the highest points of the Ridge.

There are even less geophysical data for the Norfolk Ridge than for Lord Howe Rise and no profiles available to BMR were recorded between West Norfolk Ridge and the New Zealand continental slope. Therefore in drawing the tentative boundary between the Ridge and New Zealand continental margin (Pl. 4) a saddle point between the two has been taken as the dividing line. This has been drawn from analogy with Bellona Gap.



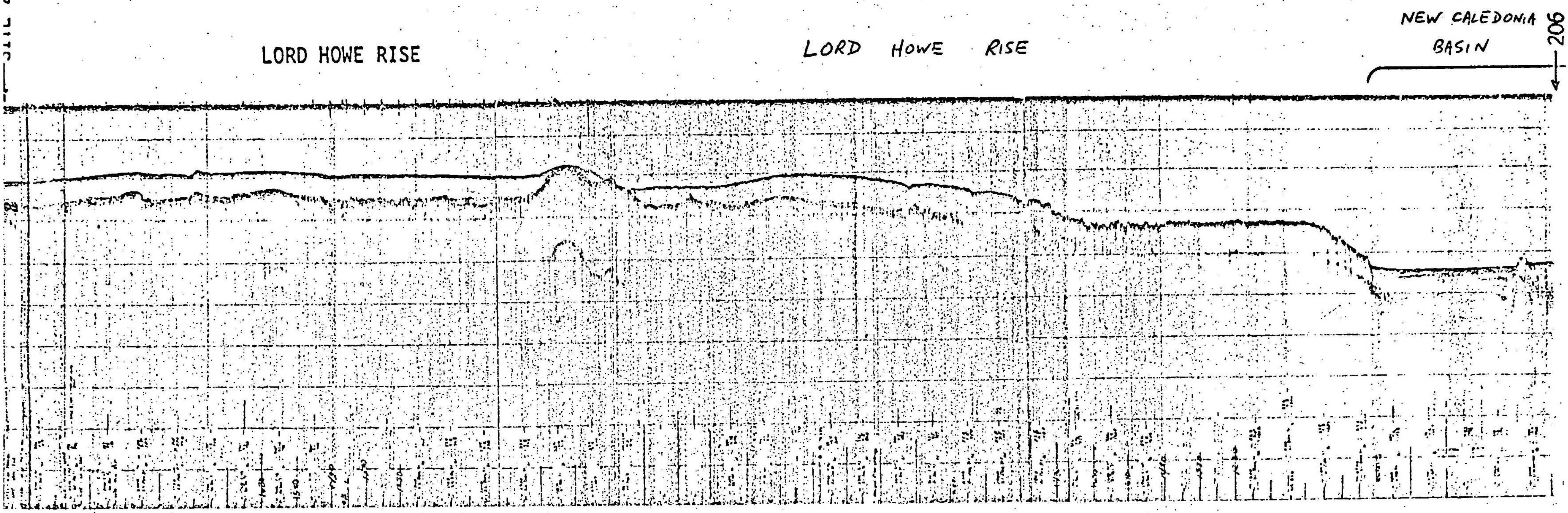
Seismic Profile recorded by Glomar Challenger during Leg 21 of DSDP.

(From: Initial Reports of the Deep Sea Drilling Project, Vol XXI)

Figure 10

Record No 1976/10

M

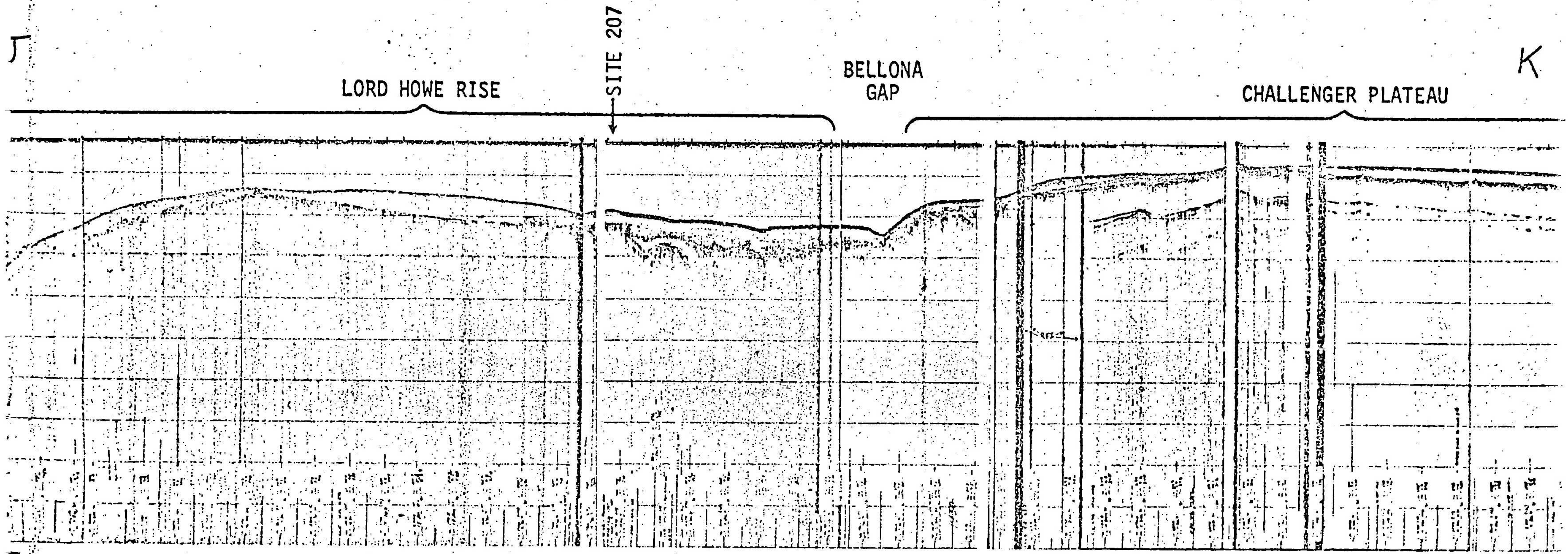


Seismic Profile recorded by Glomar Challenger during Leg 21 of D.S.D.P.

(From: Initial Reports of the Deep Sea Drilling Project, Vol XXI)

Figure 11

Record Nº 1976/10



Seismic Profile recorded by Glomar Challenger during Leg 21 of DSDP

(From: Initial Reports of the Deep Sea Drilling Project, Vol XXI)

Figure 19

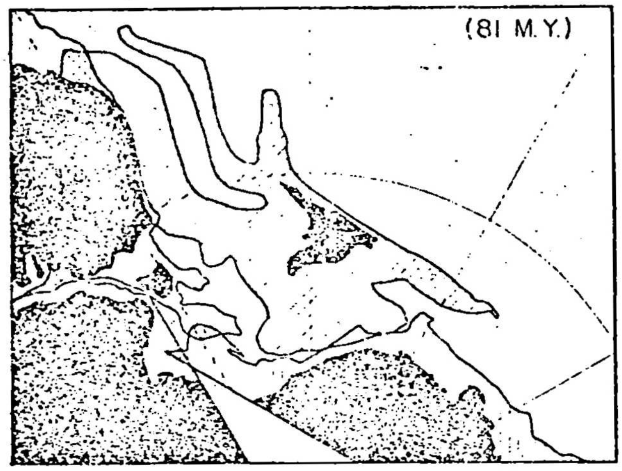
Geological evolution (Figs. 13, 14, and 15)

Results from the various geophysical surveys and deep sea drill-holes indicate (Jongsma, 1976) that Lord Howe Rise was once part of the Australia-Antarctic continent. Separation of the Rise from Australia occurred about 80 m.y. ago (Hayes & Ringis, 1973) when the oceanic Tasman Basin began to form. Sea-floor spreading in the Tasman Basin caused the Rise to rotate gradually away from Australia and to subside simultaneously. This movement ended about 50 m.y. ago. Thus the Rise is formed by a block of continental crustal material over which sediments were deposited. These sediments would initially have been derived from the Australian continental landmass to the west, but the later sediments consist mainly of biogenic oozes deposited in an open ocean.

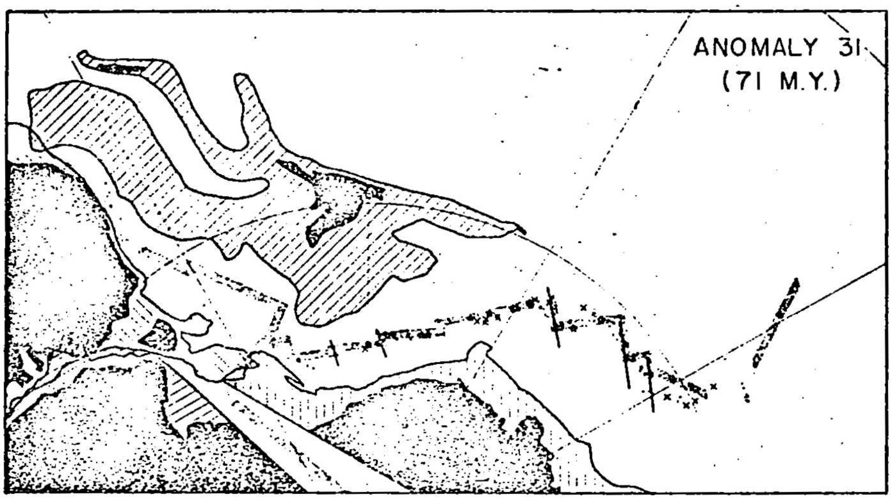
The geological evolution of Norfolk Ridge is at present more conjectural than that of Lord Howe Rise. Several hypothesis have been put forward in regard to crustal movements in this area. One explanation is that Norfolk Ridge once lay, together with Lord Howe Rise, against the eastern margin of Australia, and that sea-floor spreading in the New Caledonia Basin separated the two ridges (Jongsma, 1976). Thus Norfolk Ridge may be of similar structure to Lord Howe Rise. Seismic refraction profiles across the two ridges (Shor et al., 1971) show that they both have essentially similar crustal structures, with Lord Howe Rise underlain by a crust 25 km thick and Norfolk Ridge by crust 21 km thick.

Resources potential

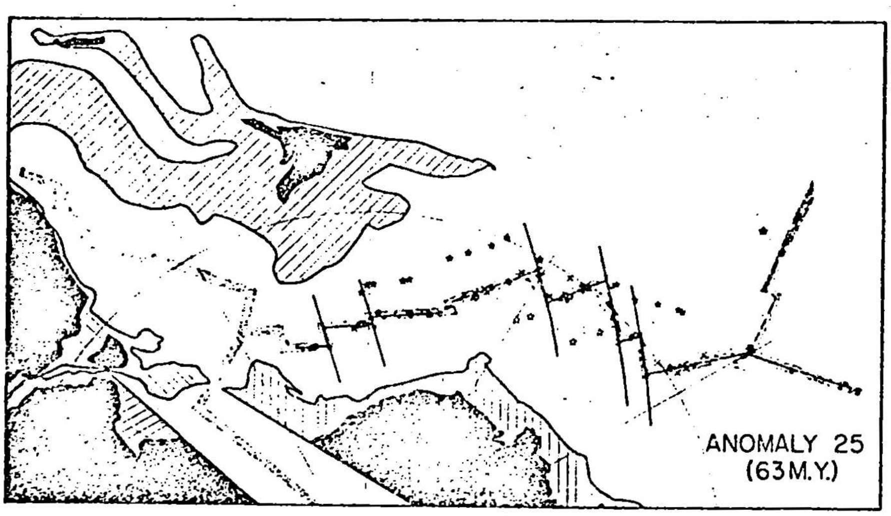
No mineral deposits have been discovered on any of the islands of Lord Howe Rise or Norfolk Ridge, and since all the islands are formed chiefly of volcanic materials, no mineralization is likely. Present knowledge is inadequate to define the petroleum potential of the two ridges. Both Lord Howe Rise and Norfolk Ridge contain small sedimentary basins with up to 3000 m of sedimentary rocks. The lower parts of this sedimentary sequence are likely to be composed of terrigenous sediments deposited when both ridges were close to the Australian landmass. Hence these sediments could form possible hydrocarbon source and reservoir rocks. The volcanic layers in the upper part of the sedimentary sequence could form reservoir cap rocks. But the deep water and remoteness of the area would make exploration and production very expensive even when the capability to produce oil from these water depths is achieved. The relatively small areal extent of the basins so far discovered precludes the possibility of finding giant oil fields. However, the sparsity of geophysical data over the area means that areas of thick sedimentary sequence could have been missed and further marine geophysical surveys are definitely recommended.



Configuration of continental fragments and plate boundaries in South Pacific about 81 My ago. Symbols same as Fig. 15 and Tasman Sea closed according to Hayes & Ringis (1973). An additional, unknown, plate boundary is probably needed to avoid the overlap of Australia and the Lord Howe Rise;



Configuration of continental fragments and plate boundaries in South Pacific about 71 My ago. Symbols same as Fig 15

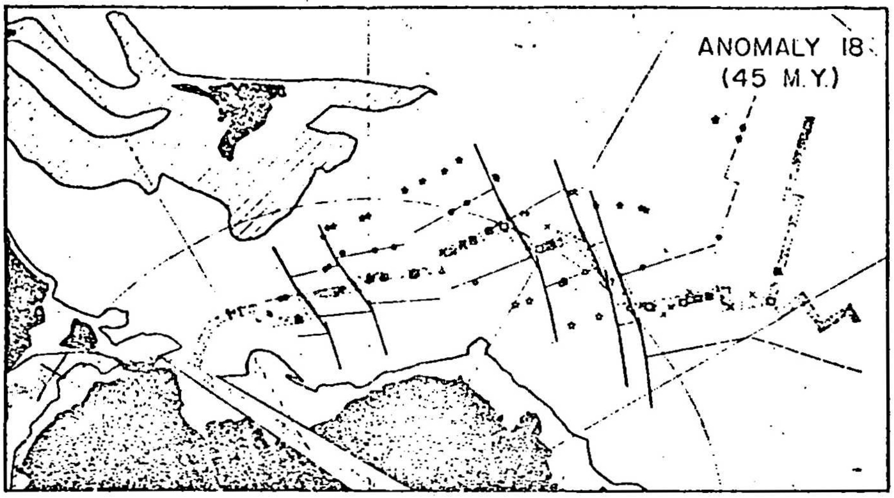


Configuration of continental fragments and plate boundaries in South Pacific about 63 My ago. Symbols same as Fig. 15, and plate motions in the Tasman Sea according to Hayes & Ringis (1973). Australia-Antarctic boundary is not yet active.

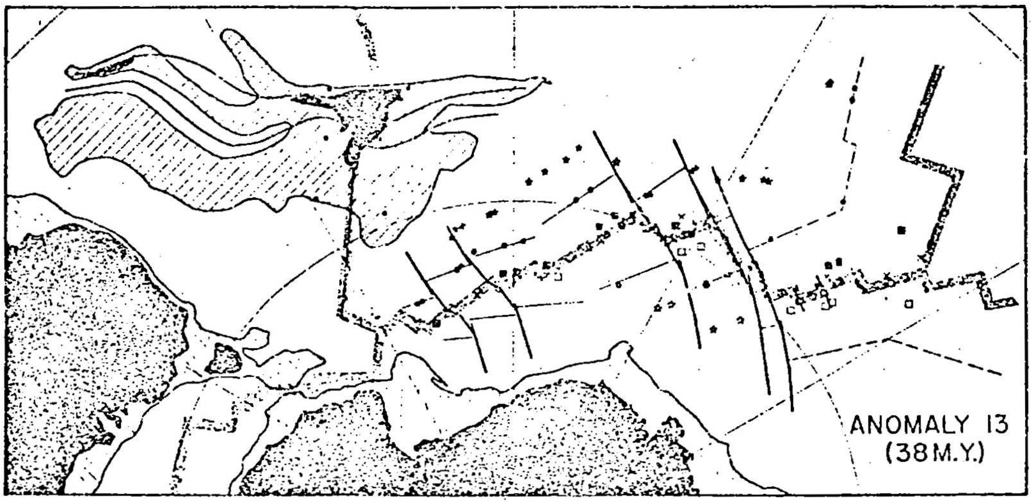
(From Molnar et al., 1975)

Record Nº 1976/10

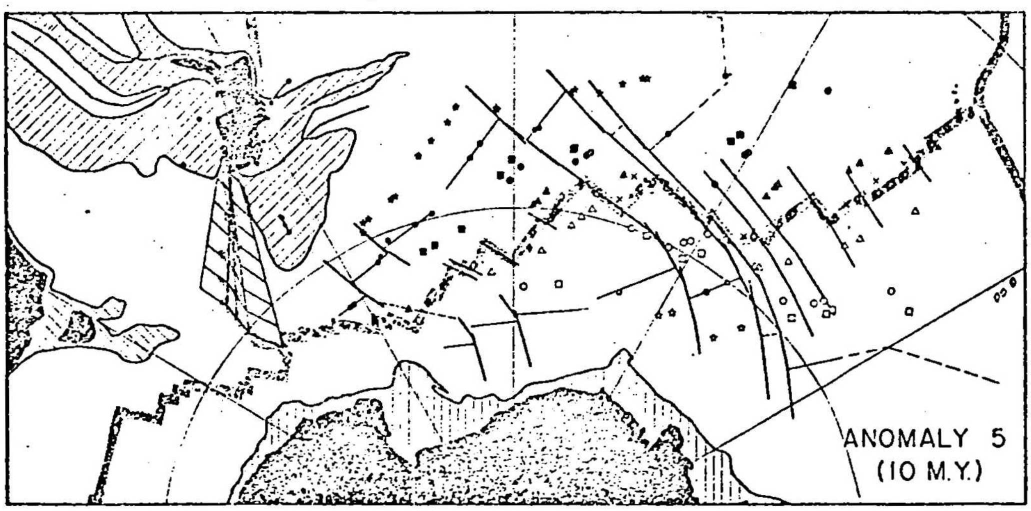
Figure 13



. Configuration of continental fragments and plate boundaries in South Pacific about 45 My ago. Symbols same as Fig 15, Plate boundary in New Zealand is not yet active.



Configuration of continental fragments and plate boundaries in South Pacific about 38 My ago. Symbols same as Fig 15



Configuration of South Pacific about 10 My ago. Symbols same as Fig. 15 Rotation parameters are in Table 2 for the South Pacific and in Weissel & Hayes (1972) for the Indian Ocean. Earthquakes and central anomalies are rotated half the distance. Amount of rigid displacement of south-eastern New Zealand with respect to the north-western part from 21 to 10 My is shown by dots connected by arrows. Actual displacement is assumed to be taken up both by faulting and by broad deformation within New Zealand.

(From Molnar et al., 1975) Record No. 1976/10 Figure 14

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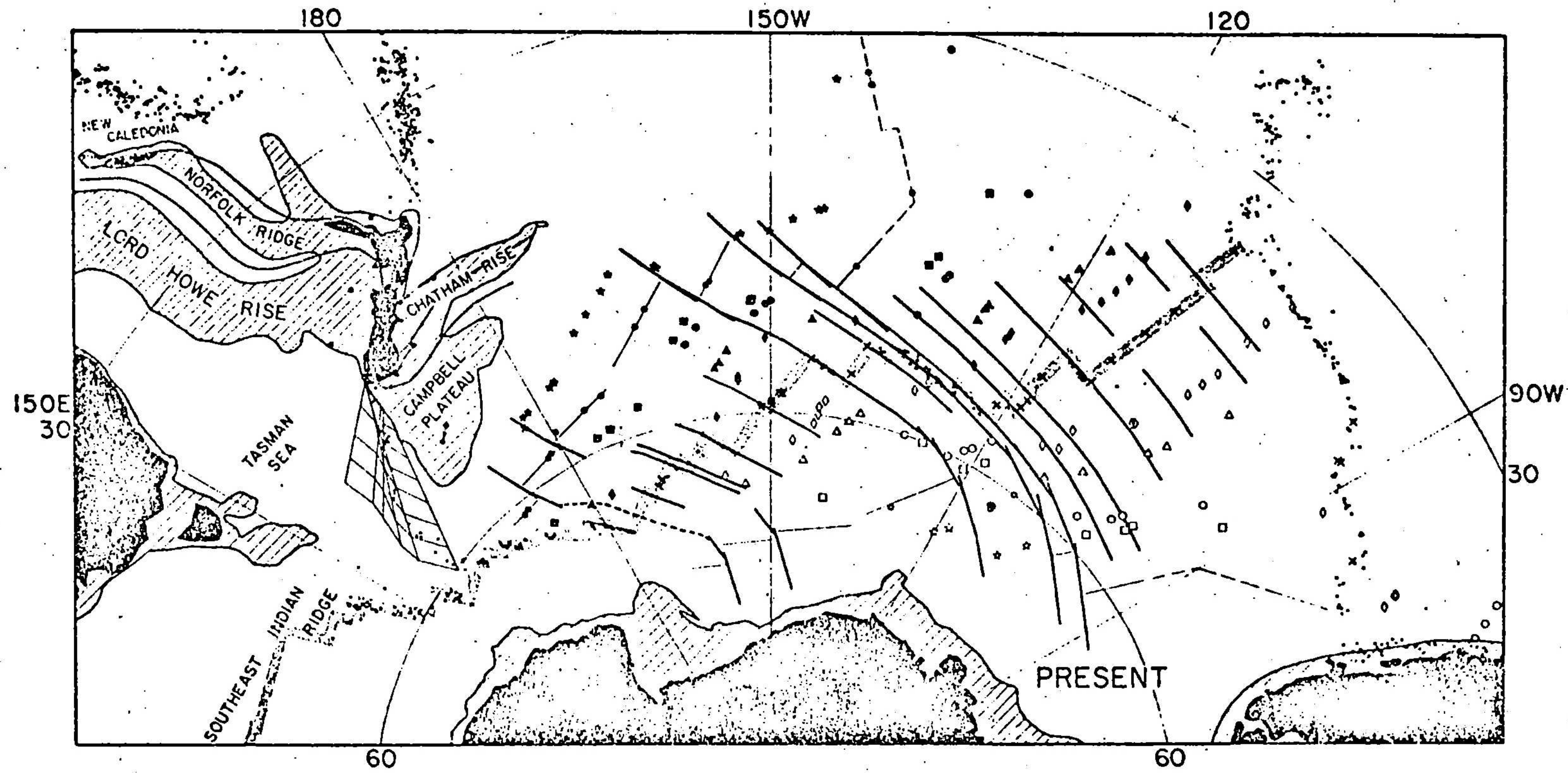

Present configuration of continental fragments, plate boundaries, fracture zones and magnetic anomalies in South Pacific. Different symbols show position of anomalies 5 (diamond), 6 (triangle), 13 (circle), 18 (square), 25 (circle with fringe) and 31 (star). Black dots show earthquake epicentres, x's are central anomalies. Earthquakes and greylines show presently active plate boundaries fracture zones are shown by heavy lines. Thinner lines show anomaly 25 locations, for reference, including the inferred position of anomaly 25 formed on the Antarctic plate by the Antarctica–Nazca spreading centre. Hatched area south of New Zealand shows amount of sea-floor formed since 38 My by Pacific–Indian spreading. Dots connected by arrows show amount of rigid motion of the south-eastern part of New Zealand with respect to the north-western part since 10 My. Belts of the New Zealand geosyncline are from Fleming (1969). In this and subsequent figures, West Antarctica and the co-ordinate system are kept fixed with respect to the bottom of the figure.

(From Molnar et al., 1975)

Figure 15

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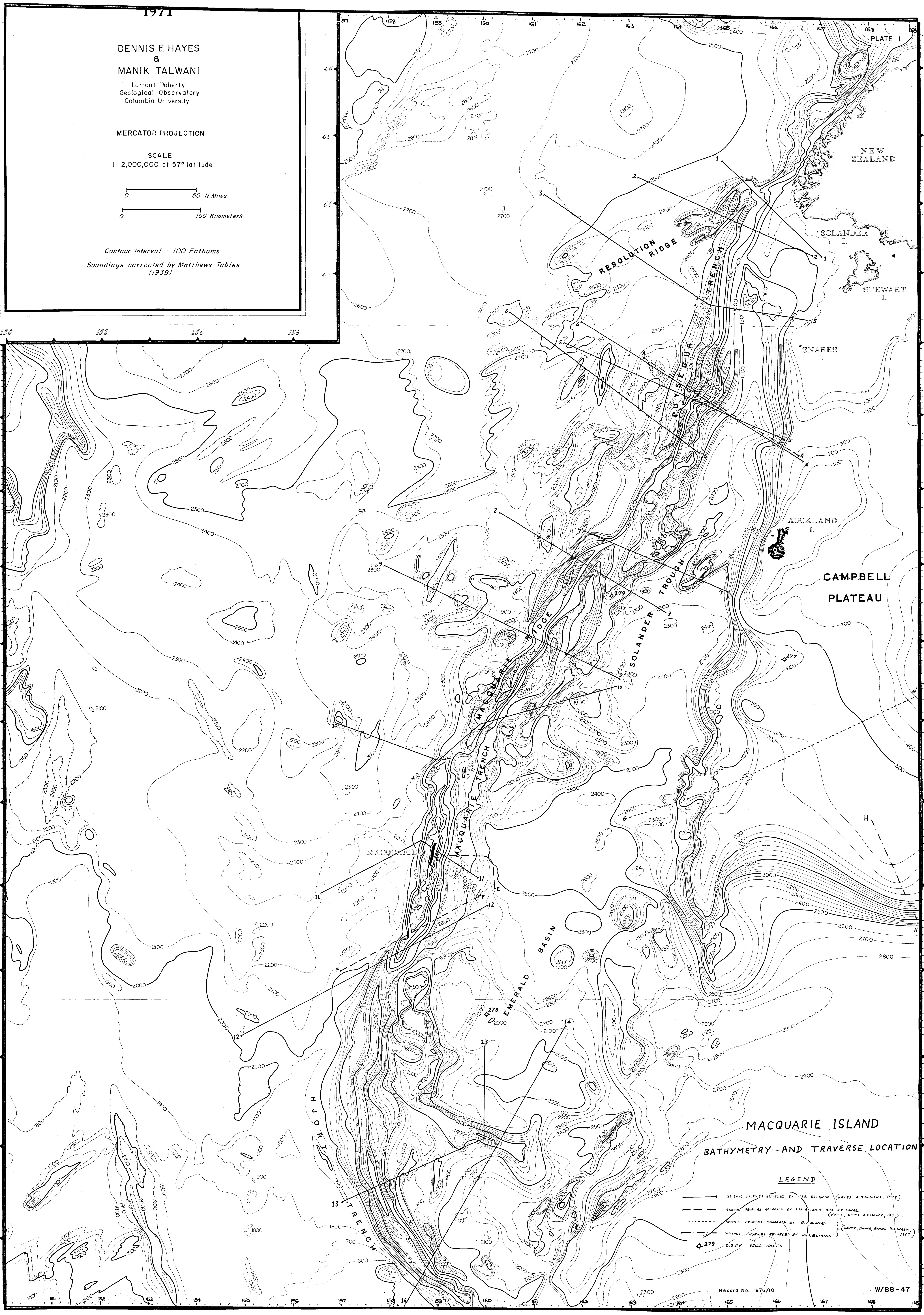

1971
DENNIS E. HAYES
&
MANIK TALWANI
Lamont-Doherty
Geological Observatory
Columbia University
MERCATOR PROJECTION
SCALE
1 : 2,000,000 at 57° latitude
50 N.Miles
100 Kilometers
Contour Interval : 100 Fathoms
Soundings corrected by Matthews Tables
(1939)
PLATE I
NEW ZEALAND
SOLANDER I.
STEWART I.
SNARES I.
AUCKLAND I.
CAMPBELL PLATEAU
RESOLUTION RIDGE
PUYSEGUR TRENCH
SOLANDER TROUGH
MACQUARIE RIDGE
MACQUARIE TRENCH
MACQUARIE
EMERALD BASIN
HJORT TRENCH
MACQUARIE ISLAND
BATHYMETRY AND TRAVERSE LOCATION
LEGEND
SEISMIC PROFILES RECORDED BY U.S.S. ELTANIN (HAYES & TALWANI, 1978)
SEISMIC PROFILES RECORDED BY U.S.S. ELTANIN AND R.V. CONRAD (HOUTZ, EWING & EMBLEY, 1971)
SEISMIC PROFILES RECORDED BY R.V. CONRAD
SEISMIC PROFILES RECORDED BY U.S.S. ELTANIN
(HOUTZ, EWING, EWING & LONARDI, 1967)
279 D.S.D.P. DRILL HOLES
Record No. 1976/10
W/B8-47


1971
DENNIS E. HAYES
&
MANIK TALWANI
Lamont-Doherty Geological Observatory Columbia University
MERCATOR PROJECTION
SCALE
1: 2,000,000 at 57° latitude
0 50 N. Miles
0 100 Kilometers
Contour Interval : 100 Fathoms
Soundings corrected by Matthews Tables (1939)
PLATE 2
NEW ZEALAND
SOLANDER I.
STEWART I.
SNARES I.
AUCKLAND I.
CAMPBELL PLATEAU
RESOLUTION RIDGE
PUYSEGUR TRENCH
SOLANDER TROUGH
MACQUARIE RIDGE
MACQUARIE TRENCH
MACQUARIE I.
EMERALD BASIN
HJORT TRENCH
MACQUARIE ISLAND
BATHYMETRY AND MORPHOLOGICAL DIVISIONS
LEGEND
LIMITS OF MACQUARIE RIDGE SYSTEM
POSSIBLE BASE OF NEW ZEALAND CONTINENTAL SLOPE OR RISE*
* THE CONTINENTAL RISE IS APPARENT IN ONLY A FEW LOCALITIES
Record No. 1976/10
W/B8-46

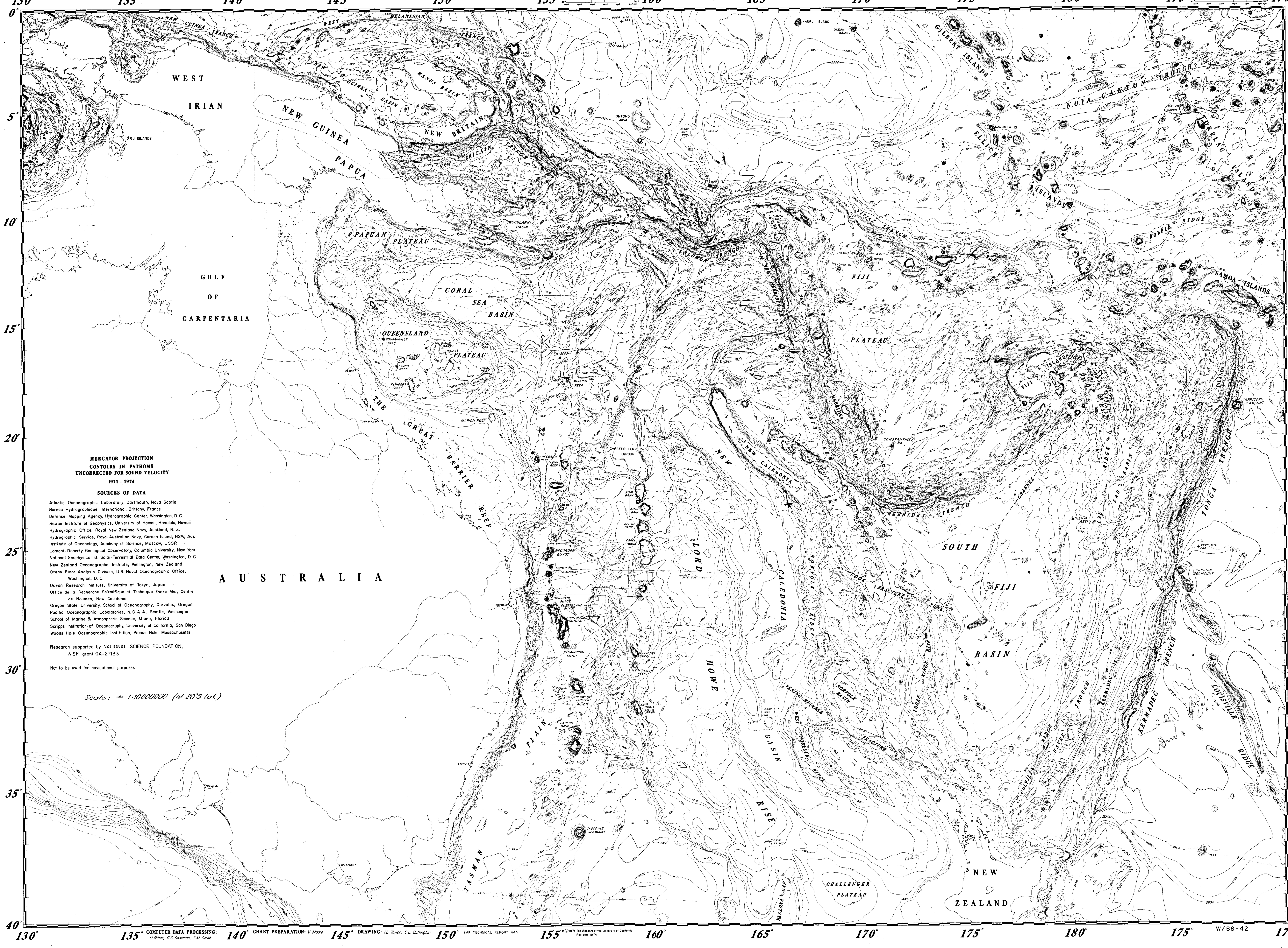
BATHYMETRY of the SOUTH PACIFIC

BY
J. Mammerickx, T.E. Chase, S.M. Smith, and I.L. Taylor
Scripps Institution of Oceanography

Chart No. 11 of 21

PLATE 3

Chart No. 12 of 21



W/B8-42

LORD HOWE RISE AND NORFOLK RIDGE
BATHYMETRY

Record No. 1976/10

BATHYMETRY of the SOUTH PACIFIC

BY
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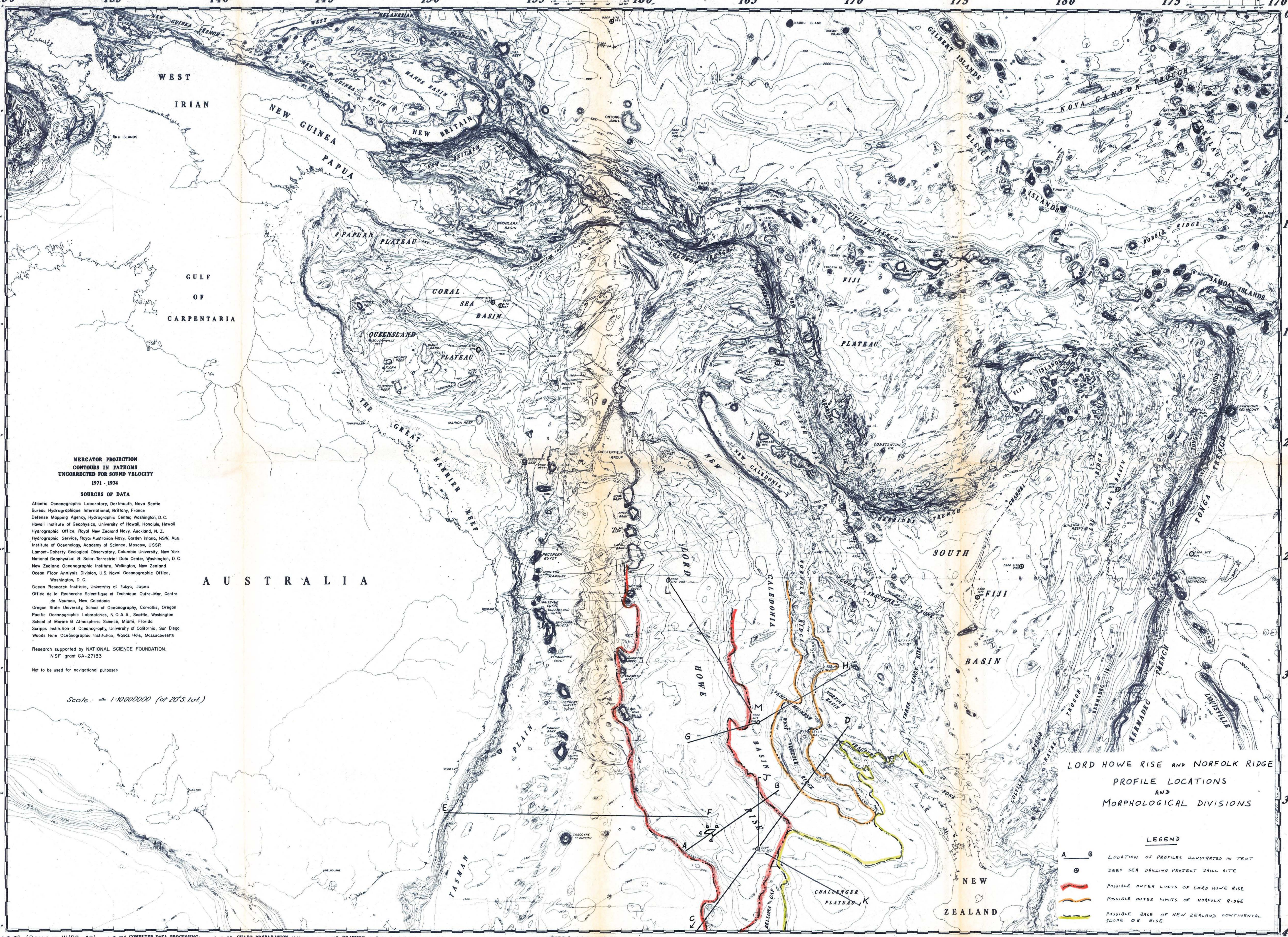
Chart No. 11 of 21

PLATE 4

Chart No. 12 of 21



(Based on W/B8-42) COMPUTER DATA PROCESSING: U Ritter, G.S Sharman, S.M Smith CHART PREPARATION: V Moore DRAWING: I.L Taylor, C.L Buffington IMR TECHNICAL REPORT 44A

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Record No. 1976/10

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