INTERNATIONAL SYMPOSIUM
ON GEODYNAMICS IN SOUTH-WEST PACIFIC
NOUMEA (NEW CALEDONIA) 27 AUGUST-2 SEPTEMBER 1976
EDITIONS TECHNIP, PARIS 1977, pp. 145-154

NEW CALEDONIA BASIN–FAIRWAY RIDGE : STRUCTURAL AND SEDIMENTARY STUDY

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Abstract Austradec I and II marine seismic surveys carried out in 1972 and 1973 by the IFP-CEPM-ORSTOM group in the southwestern Pacific contributed to the exploration of the structural elements located between Lord Howe Rise and Norfolk Ridge, investigated the sedimentary fills in accordance with data from DSDP boreholes, and pointed out the importance of volcanic alignments.

The leading structural element discovered by these surveys was the Fairway Ridge beginning at Fairway Reef in the North. Two of us (C.E. de Broin and C. Ravenne) consider that this ridge prolongs into West Norfolk Ridge towards the South.

The discovery of this ridge thus leads us to divide the New Caledonia Basin into an eastern New Caledonia Basin sensu stricto and a western Fairway Basin.

A study of seismic facies and data from DSDP boreholes enables us to suggest that the fill in the New Caledonian Basin sensu stricto is mainly of turbidite origin and that in the Fairway Basin is mainly pelagic except in its southern part. The proportion of elements derived from volcanism is considerable in both basins.

Lastly, we clearly delimit two volcanic alignments, i.e. one located in the eastern part of Lord Howe Rise, and the other in the western part of Norfolk Ridge.

In this paper we first describe the structural elements, and then we show how magnetic data confirm our hypotheses, before examining the sedimentary series.

GEOGRAPHIC SITUATION

The area investigated is located in the South West Pacific (fig. 1). It is framed by Lord Howe Rise in the West and Norfolk Ridge in the East. It is bounded in the North at the latitude of New Caledonia and in the South by the northermost tip of West Norfolk Ridge.

GEOTECTONIC SITUATION

This area is located in a mixed marginal zone context bounded by a continental area, Australia in the West and oceanic zones of recent origin in the East, i.e. the Tasman Sea, the South Fiji Basin and the North Loyalty Plateau.

The crust varies in thickness there, ranging from a semicontinental thickness of 20 to 30 km under Lord Howe Rise and Norfolk Ridge to a semioceanic thickness of about 15 km under the basin (Shor et al., 1971).

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PREVIOUS WORK

It consisted mainly in bathymetry (maps by Scripps Institution of Oceanography and New Zealand Oceanogr. Inst.) and in seismic refraction (Shor et al., 1971). On the other hand the DSDP boreholes are a valuable contribution to the understanding of the lithology and of marine unconformities (R.E. Burns, J.E. Andrews et al., 1973). Besides the seismic reflection profiles by Mobil Oil Co published by F.P. Bentz (1974), no other seismic reflection survey has been done in this area.

DATA

For this paper, we have made use of *GEORSTOM* seismic lines recorded by *ORSTOM* and especially of Austradec multitrace seismic-reflection profiles recorded by that *IFP-CEPM-ORSTOM*.

An interpretation ot the magnetic anomalies was attempted, also using data from the Austradec and Georstom profiles.

STRUCTURAL FEATURES

1. Fairway Ridge.

This is a new feature revealed by our surveys on the basis of seismic reflection and magnetism data. We began to suspect its existence in 1973 (Dubois et al., 1974).

Fairways Ridge is a major structural feature in the South West Pacific as are Lord Howe Rise and Norfolk Ridge (fig. 2 and 3). It divides the New Caledonia Basin into two sub-basins and plays an important role as a barrier in the distribution of sediments.

It appears as a basement ridge (seismic facies, magnetic signature, geologic framework) about 70 km wide (fig. 4, 5 a, b, c) and nearly 1,500 km long.

The magnetic signature of this ridge is characteristic. This aspect will be discussed later in this paper.

The ridge runs almost parallel to Norfolk Ridge and follows the same directional changes.

The central part of the ridge, which is the longest part (about 700 km), trends to the North. It abruptly changes its direction at the level of Fairway reef West of New Caledonia. In the North it is localized underneath the flank of Landsdown Bank which bounds Lord Howe Rise. Fairway Ridge ends abruptly at 19° S latitude, in a roughly East-West trending fracture zone.

To the South, West Norfolk Ridge extends in the exact prolongation of Fairway Ridge. Two of us (C. Ravenne and C.E. de Broin) consider that West Norfolk Ridge is the Southern part of Fairway Ridge. The other three authors divide it into two structural élements of different origin.

The axis of Fairway Ridge divides into two sub-parallel alignments of basement in West Norfolk Ridge where they delimit a narrow basin. West Norfolk Ridge curves South East in its southern tip (fig. 2).

Fairway Ridge is shallow at both ends and progressively becomes deeper and buried to 3,000 m in its middle part. Under a thin layer of sediments, its substratum has a characteristic seismic facies (fig. 5 a, b, c) with a strong reflector overlying a blind zone. In this it differs from Lord Howe Rise and Norfolk Ridge where the substratum reveals organized reflections. The presence of these reflections and the thickness of the underlying crust from refraction data (Shor, 1971) appears to prove that both these ridges are of the semicontinental type. Despite the absence of seismic refraction on Fairway Ridge, magnetic anomalies and the absence of any organized reflection suggest that the substratum is mainly of volcanic origin (cf. the study of magnetic anomalies described hereunder).

The sedimentary cover on this ridge is very thin at either end, up to two to three hundred meters. It gradually becomes thicker in the middle part where the ridge is buried under the sedimentary series of the New Caledonia Basin.

It is obvious that the origin of this ridge lies within the geotectonic evolution of the South West Pacific, but it is even more difficult to say how it was created. Perhaps it was a frontal bulge of oceanic crust in front of a subduction zone located to the East as suggested by Dubois et al., (1974). However, perhaps it is a former volcanic alignment like the Lord Howe Guyots or possibly a former volcanic arc corresponding to one of the subduction stages between the Australian and Pacific plates.

2. Fairway Basin (fig. 2, 3, 4, 6 a, b, c).

We call Fairway Basin that part of New Caledonia Basin "sensu lato" which is located between Lord Howe Rise and Fairway Ridge. We keep the name South New Caledonia Basin for the southern part of this basin between West Norfolk Ridge and Lord Howe Rise.

Its size and trend are identical to those of the ridges surrounding it because it occupies the entire depression between these ridges.

According to our profiles, it appears to end in the North at Landsdown Bank.

In its central part, West of Norfolk Island, the basin lies under 3,200 m of water. This depth decreases gradually towards its ends, although leveling off at around 3,000 m in front of West Norfolk Ridge. The deepening of Fairway Ridge in its middle part eliminates its role as a barrier between Fairway and New Caledonia Basins, thus changing the distribution of the sediments.

The basement of this basin is clearly delimited in some places by a powerful reflector revealing considerable diffractions (fig. 6 b). In other places, the substratum is poorly defined because it is masked by diffracting reflectors (volcanic series ?) or by thick series.

The sedimentary fill (fig. 2) is generally about 2,000 m thick. Two much thicker areas were found. One in the northern part of the basin right off the southern tip of New Caledonia is probably linked to the degradation of the reliefs of Landsdown and Fairway Banks as well as to the Volcanic outflows underlining the contact between Lord Howe Rise and Norfolk Ridge, the other located to the South of West Norfolk Ridge with a thickness of about 3,000 m of sediments is probably linked to the degradation of West Norfolk Ridge and the proximity of New Zealand.

A rise of the basement west of the Northern tip of West Norfolk Ridge forms a small threshold that divides the basin in its lengthwise direction.

At the contact between Fairway Basin and Lord Howe Rise, we found a volcanic alignment on the eastern flank of Lord Howe Rise (high axis in fig. 2). Some evidence of this volcanism has been presented by F. Bentz (1974). This alignment occurs in the shape of a string of seamounts buried within a sedimentary series. The upper part of this string roughly corresponds to the Oligocene unconformity. Some of these volcanoes were later reactivated by subsequent tectonic activity.

3. New Caledonia basin Sensu Stricto (fig. 2, 3, 4, 7 a, b, c).

What we call New Caledonia Basin sensu stricto is the basin between Fairway Ridge and Norfolk Ridge. This basin is much smaller in size (about 1,000 km long) than the other structures because Wanganella Bank between West Norfolk Ridge and Norfolk Ridge (fig. 3) closes it off in its southern part. To the North it is closed off at the fracture zone bounding Fairway Ridge. The northern end of the New Caledonia Basin, i.e. the part located off New Caledonia, has previously been described (Dubois et al., 1970). We should just note the presence of a small basin (fig. 7 c) to the South of New Caledonia, between New Caledonia Basin sensu stricto and Norfolk Ridge, as was revealed by Dupont et al., (1975).

New Caledonia Basin s.s. has an even flat bottom at a depth of about 3,600 m.

Under a sedimentary blanket 2,000 to 3,000 m thick, a basement can be seen that is highlighted on the seismic profiles by a strong reflector (fig. 7 a) on top of a great many diffractions.

4. Norfolk Ridge (fig. 2, 3, 4).

It stretches nearly 1,500 km between the North Western tip of New Zealand and New Caledonia. Two of us (C.R. and C.E. de B.) assume that Norfolk Ridge is linked to the North Western tip of New Zealand through the Vening Meinesz fracture zone. The corresponding offset might have been caused by the opening up of the Tasman Sea farther to the South West. To the North, it extends into New Caledonia. Norfolk Ridge is dissymmetric. The sedimentary series there are tilted towards the East. The western edge is made up by an alignment of volcanic intrusions. This alignment appears to extend into the western volcanic "sillon" (P. Routhier, 1973) of New Caledonia.

The different sedimentary series and their age were recently described by J. Dupont et al. (1975). The position of this ridge linking two areas having almost exactly the same geological history (New Caledonia and the Auckland region) (A.R. Lillie and R.N. Brothers, 1970) as well as the sedimentary series characteristics from seismic data suggest that this ridge has undergone the same geological history as what is known at its two ends.

Norfolk Ridge separates two very different sedimentary provinces, i.e. in the West New Caledonia Basin with its thick sedimentary fill, and in the East a complex region bare of sediments and apparently of recent origin.

ANALYSIS OF MAGNETIC ANOMALIES

Magnetic anomalies have made a very valuable contribution to the structural knowledge of the unit till now called New Caledonia Basin. The magnetic relief is quite different from that over the neighboring Lord How Rise and Norfolk Ridge. Whereas across those rises the magnetic anomalies are diverse and intense (Lapouille, this volume; Launay et al., this volume), here they are well characterized.

A positive magnetic anomaly with a long wavelength, more than one hundred kilometers long and several hundred gammas in amplitude, extends along the length of New Caledonia Basin where it can be seen on all the profiles crossing the basin (fig. 8). This positive anomaly, sometimes divided into two parts, takes its origin in the eastern border of Lansdown Bank. A reduction in the magnetic pole (Galdeano, 1974) of the profile crossing the area above Lansdown Bank, assuming the remanent magnetism to be oriented like the present magnetic field, also induces a slight phase displacement of the magnetic anomalies to the East (fig. 9). We can thus suggest that the corresponding geological structure has its origin on the eastern border of Lansdown Bank. A three kilomete upward prolongation of this profile (Galdeano, 1974) emphasizes the breadth of this anomaly whose corresponding geological structure is thus quite deep-seated. A geological model defined by its magnetic susceptibilities (Lapouille, this volume) will prove these conclusions that the so-called Fairway Rise structure should be seated to the North East and under Lansdowne Bank. It is represented by a magnetic susceptibility ranging to 13.10^{-3} c.g.s. corresponding to a basaltic body. Its magnetic characteristics thus suggest that Fairway Ridge is a magnetic rise. This is shown accross the filtered regional profiles which cross it (Lapouille, this volume), and it joins West Norfolk Ridge in the South via the Vening Meinesz Fracture Zone.

This magnetic rise is separated from the continental Lord Howe Rise by a narrow basin we call Fairway Basin. This basin is characterized by a negative magnetic anomaly of high amplitude, several hundred gammas, whose wavelength is equal to the basin width.

The reduction in the pole of the profile crossing Lansdown Bank (fig. 9) reveals the characteristic magnetic minimum of the basin, while the upward prolongation of this profile removes the high frequencies of the variations which are thus due to a topographical effect, since the seafloor is very close to the sea level there. The substratum, as shown by magnetic anomalies, is thus higher in the northern part of the basin.

The New Caledonia Basin sensu stricto, which is then reduced to the area located between Fairway Rise and New Caledonia-Norfolk Ridge, is characterized by a lack of well-marked magnetic anomalies. This area is magnetically well contrasted and distinguished from the neighboring ridges which are marked by large positive anomalies outlining Fairway Ridge on one hand and basaltic uplifts on the slope between Norfolk Ridge and the New Caledonia Basin on the other hand. The magnetic variations here are extremely slight, the amplitudes very low and the wavelengths not well defined. The great depth of the basaltic basement (overlain by a thick sedimentary layer) could explain the relative lack of magnetic variations.

SEDIMENTARY SERIES

In the basins, seismic profiles enabled us to distinguish up to three main sedimentary series separated by unconformities. Data from DSDP boreholes of leg 21, together with the known land geological history (Lillie and Brothers, 1970) enable us to propose the following ages for the main unconformities.

- Unconformity 1, which is found throughout the entire area examined, corresponds in

the boreholes to a gap between the Upper Eocene and Lower and Middle Oligocene. The unconformity is especially obvious on the ridges and on the edges of the basin. In the middle of the basins the series are often conformable, and the problem can be raised of the possible existence of a more complete series.

- Unconformity 2, is probably situated in the Upper Cretaceous. It is sometimes confused with the acoustic basement.

- Unconformity 3, which is not reached in the boreholes, corresponds on seismic profiles to different phenomena. Whereas in New Caledonia Basin and on Fairway Ridge it overlies an obvious acoustic basement, it appears on the contrary on Lord Howe Rise, Norfolk Ridge and the western border of Fairway Basin to correspond to a strong unconformity separating series of sedimentary origin (Dubois et al., 1974). It is not obvious that this unconformity observed on the seismic sections corresponds to a synchronous phenomenon throughout the whole area.

DSDP boreholes, seismic facies and formations known on land suggest that sediments are mainly pelagic in Fairway Basin and in the central part of New Caledonia Basin. Near emerged land (New Caledonia) or very shallow ridge (West Norfolk Ridge) the fill looks more turbiditic (fig. 7 c), probably with a high proportion of volcanic elements.

The two upper series thin out considerably on the ridges, and unconformities 1 and 2 are often found to merge. On the other hand, mainly on Lord Howe Rise, there is a considerable development of the underlying series under unconformity 3 (Dubois et al., 1974).

CONCLUSION

The area under investigation is a transition zone in which the convergence of the Austral-Indian continental plate and the oceanic Pacific plate is revealed during its evolution by a succession of fossil island arcs with associated structures and elements detached from the Australian margin.

The structural elements making up this region are, for the most part, stretched out along a submeridian direction.

They bend towards the North West in the North and towards the South East in the South. These bends appear to have been caused by spreading in the North Loyalty and North Fiji Plateaus in the North and by the creation of the Tasman Sea in the South.

Three of these elements whose structure is described in this paper - Fairway Basin and Ridge and New Caledonia Basin s.s. - gradually become deeper in their middle part at the latitude of Norfolk Island.

Fairway Ridge, which is the structural element that we reveal, is probably an element associated with an active fossil margin (frontal bulge, former alignment or volcanic arc).

Fairway Basin and New Caledonia Basin s.s., whose substratum reveals no organized reflection and whose crust is thin, are basins probably created in connection with the building of former island arcs (inter-arc or marginal basin). The sedimentary fill indicates that the age of creation was older than late Cretaceous and at most jurassic.

Acknowledgments We thank *ORSTOM*, *IFP*, *CFP*, *ELF/ERAP* and *SNPA* for permission to publish this paper. We are indebted to the officers and crews of the N.O. Coriolis and Noroit from *CNEXO* and to J.P. Fail and R. Donatien which were geophysicists during Austradec II cruise.

We are grateful to M. Poulet and G. Grau for their critical reading of this paper.

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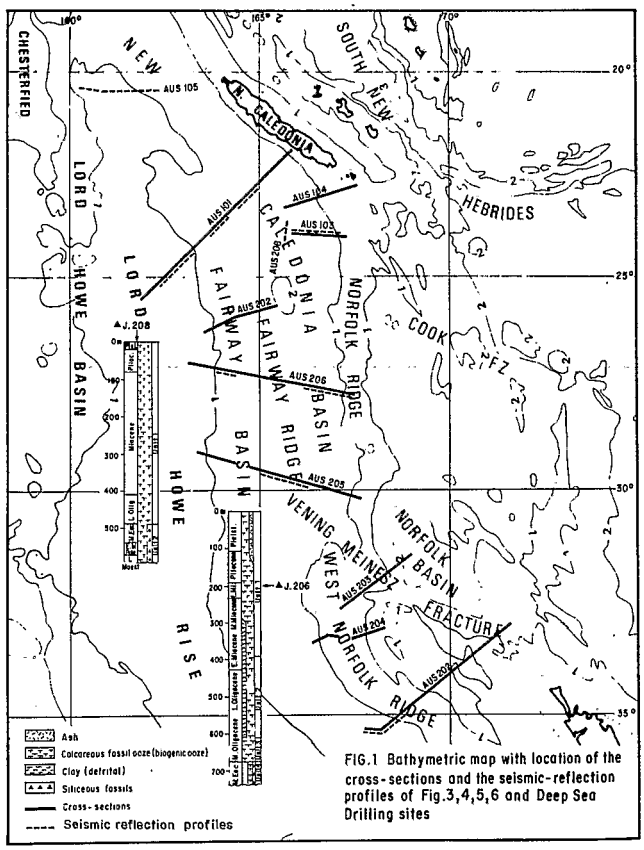


FIG.1 Bathymetric map with location of the cross-sections and the seismic-reflection profiles of Fig.3,4,5,6 and Deep Sea Drilling sites

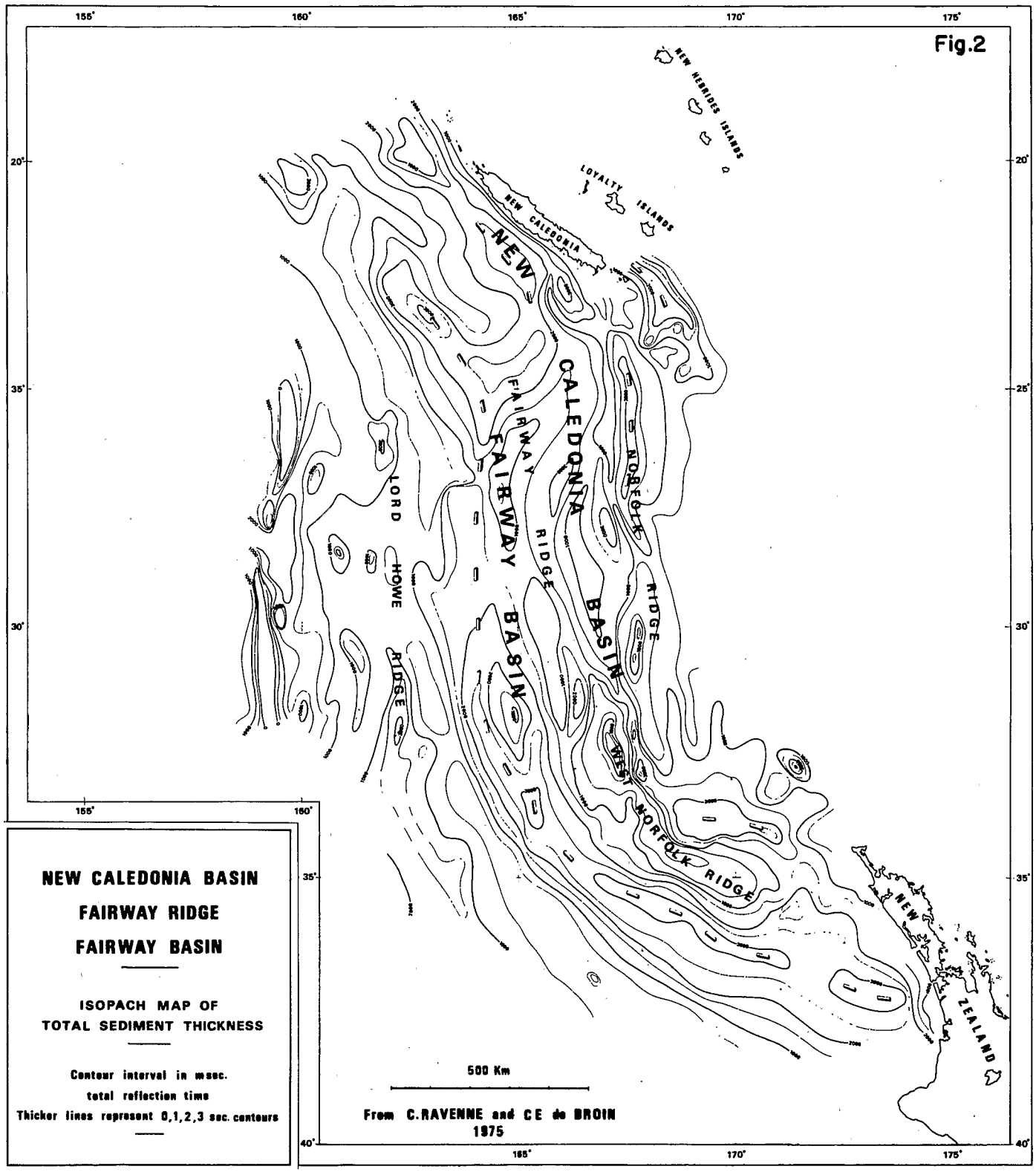


Fig.2
155°
160°
165°
170°
175°
20°
25°
30°
35°
40°
NEW HEBRIDES ISLANDS
LOYALTY ISLANDS
NEW CALEDONIA
NEW CALEDONIA BASIN
FAIRWAY RIDGE
FAIRWAY BASIN
NORFOLK RIDGE
LORD HOWE RIDGE
WEST NORFOLK RIDGE
NEW ZEALAND
500 Km
From C.RAVENNE and C E de BROIN
1975
NEW CALEDONIA BASIN
FAIRWAY RIDGE
FAIRWAY BASIN
ISOPACH MAP OF
TOTAL SEDIMENT THICKNESS
Contour interval in msec.
total reflection time
Thicker lines represent 0,1,2,3 sec. contours

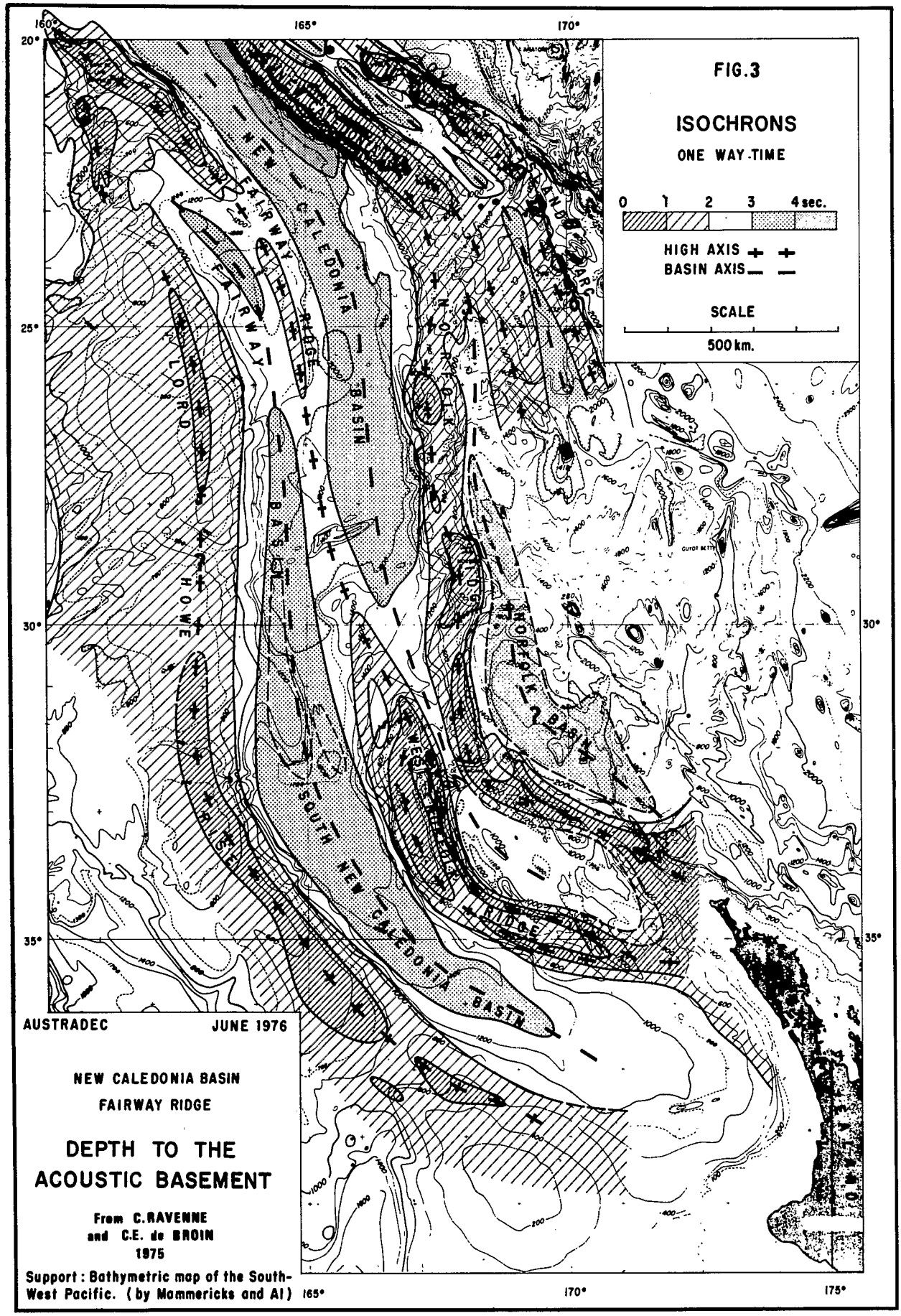
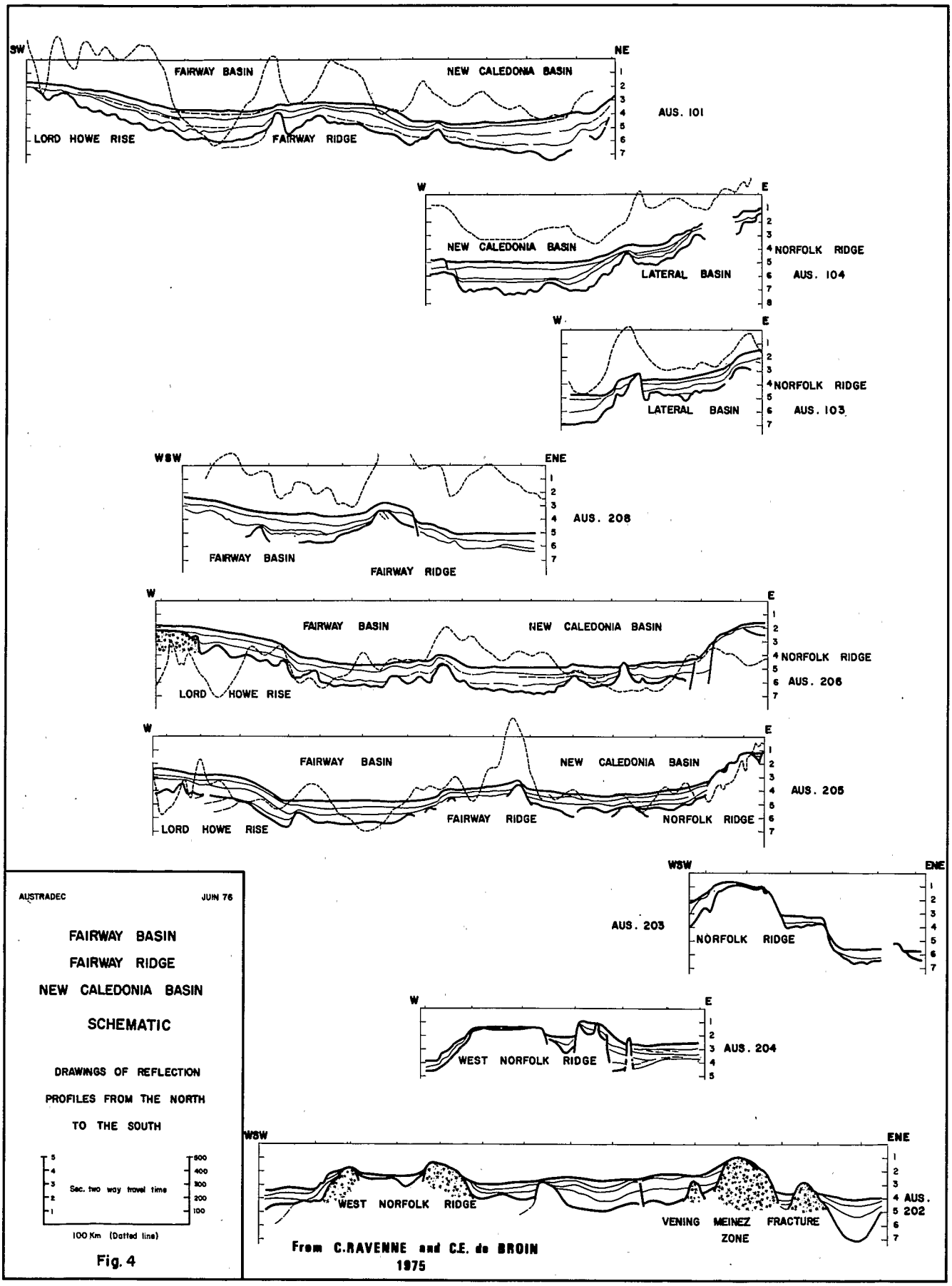


FIG.3
ISOCHRONS
ONE WAY-TIME
0 1 2 3 4 sec.
HIGH AXIS
BASIN AXIS
SCALE
500 km.
160°
165°
170°
175°
20°
25°
30°
35°
NEW CALEDONIA BASIN
FAIRWAY RIDGE
NORFOLK RIDGE
NORFOLK BASIN
LORD HOWE RISE
SOUTH NEW CALEDONIA BASIN
AUSTRADEC JUNE 1976
NEW CALEDONIA BASIN
FAIRWAY RIDGE
DEPTH TO THE ACOUSTIC BASEMENT
From C.RAVENNE and C.E. de BROIN 1975
Support : Bathymetric map of the South-West Pacific. (by Mammericks and Al)


SW
NE
FAIRWAY BASIN
NEW CALEDONIA BASIN
LORD HOWE RISE
FAIRWAY RIDGE
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LATERAL BASIN
NORFOLK RIDGE
AUS. 104
W
E
NORFOLK RIDGE
LATERAL BASIN
AUS. 103
WSW
ENE
AUS. 208
FAIRWAY BASIN
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NEW CALEDONIA BASIN
NORFOLK RIDGE
LORD HOWE RISE
AUS. 206
W
E
FAIRWAY BASIN
NEW CALEDONIA BASIN
AUS. 205
LORD HOWE RISE
FAIRWAY RIDGE
NORFOLK RIDGE
AUSTRADEC
JUIN 76
FAIRWAY BASIN
FAIRWAY RIDGE
NEW CALEDONIA BASIN
SCHEMATIC
DRAWINGS OF REFLECTION
PROFILES FROM THE NORTH
TO THE SOUTH
Sec. two way travel time
100 Km (Dotted line)
WSW
ENE
AUS. 203
NORFOLK RIDGE
W
E
WEST NORFOLK RIDGE
AUS. 204
WSW
ENE
WEST NORFOLK RIDGE
VENING MEINEZ FRACTURE ZONE
AUS. 202
From C.RAVENNE and C.E. de BROIN
1975

Fig. 4

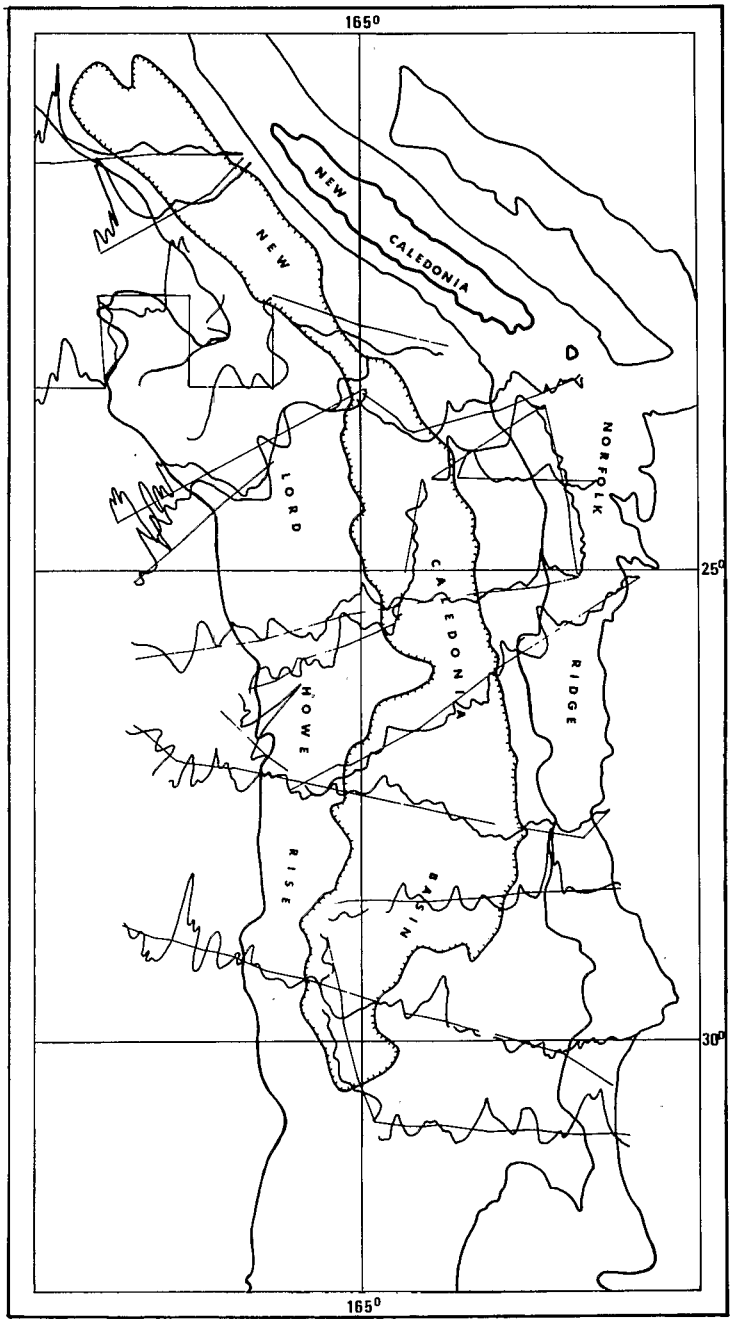

Fig.8 Magnetic anomalies in the area of New Caledonia Basin and surroundings

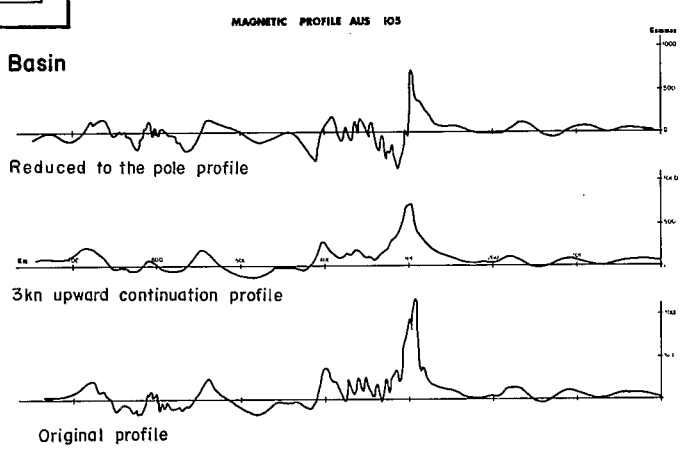

Fig.9 Reduction to the North magnetic pole and upwards prolongation of magnetic profile AUS 105

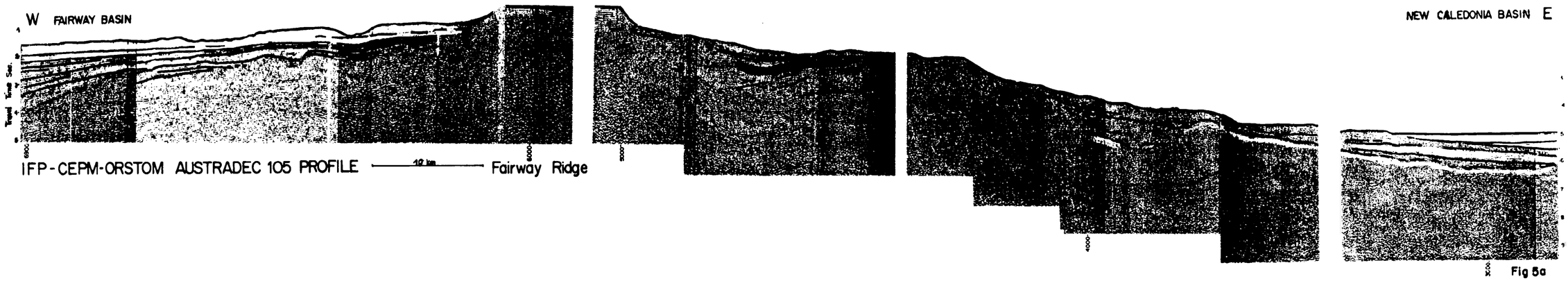

Fig 5a

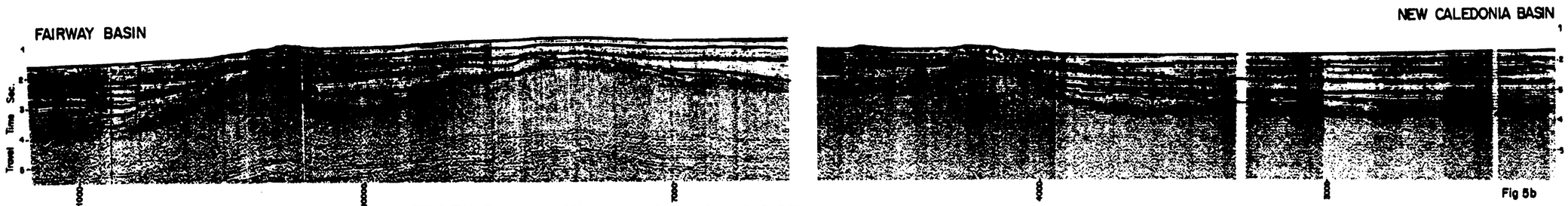

Fig 5b

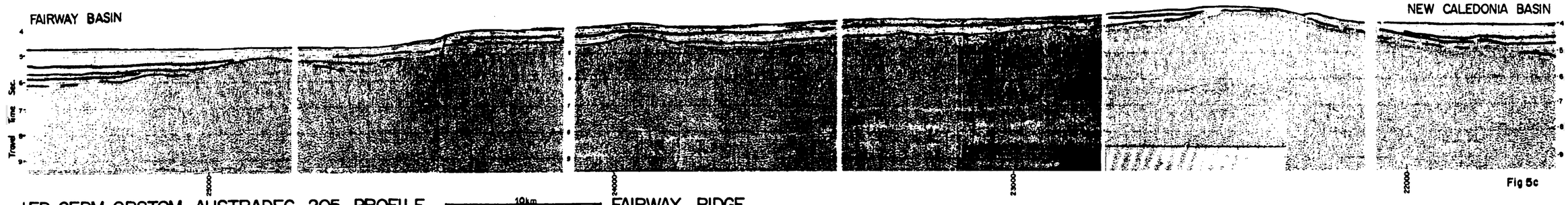

Fig 5c

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Pour A0 et A1: ABERPFTHLIJDOCGQUVWMNSZXKY
zsaeocmuvnwxirfkhbdpqgyjlt 7142385690
Pour A2,A3,A4: ABERPFTHLIJDOCGQUVWMNSZXKY
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0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

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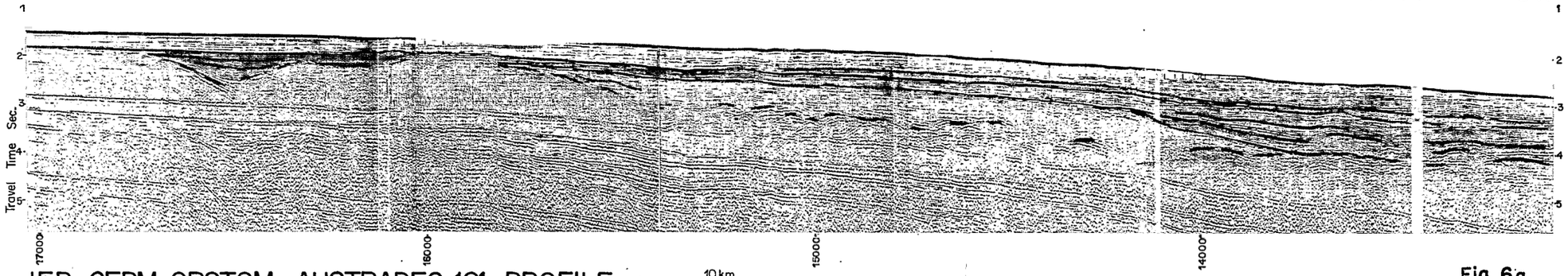
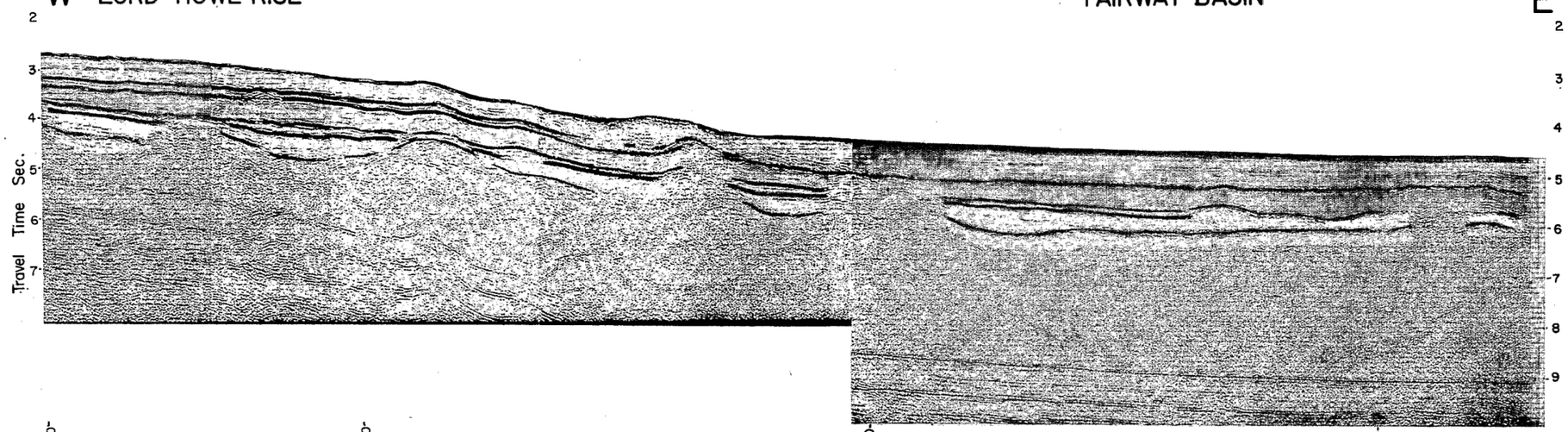
NE LORD HOWE RISE — FAIRWAY BASIN SW



IFP-CEPM-ORSTOM AUSTRADEC 101 PROFILE — 10 km

Fig. 6a.

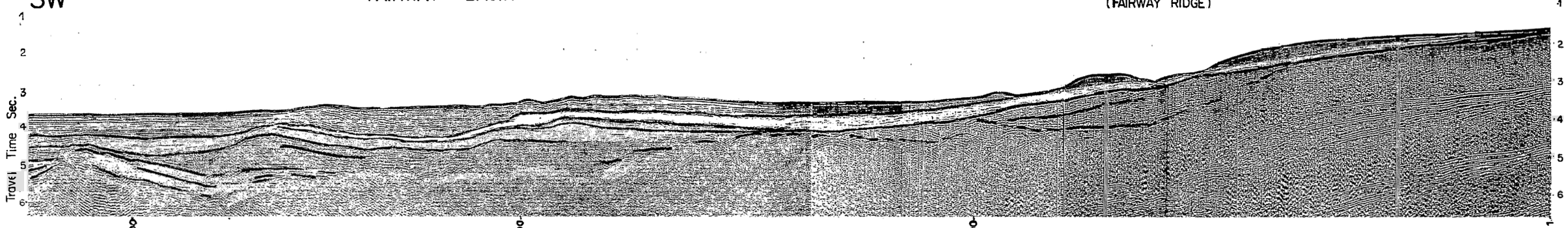
W LORD HOWE RISE — FAIRWAY BASIN E



IFP-CEPM-ORSTOM AUSTRADEC 206 PROFILE — 10 km

Fig 6b

SW — FAIRWAY BASIN — WEST NORFOLK RIDGE (FAIRWAY RIDGE) — NE



IFP-CEPM-ORSTOM-AUSTRADEC 202 bis PROFILE — 10 km — Fairway Ridge — 10 km (SOUTHERN EXTREMITY)

Fig 6c

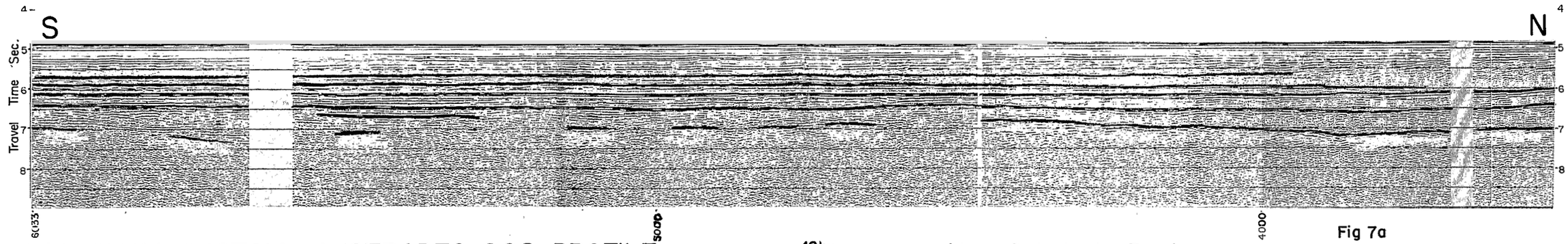


Fig 7a

IFP - CEPM - ORSTOM AUSTRADEC 208 PROFILE — 10km — New Caledonia Basin (Central Part)

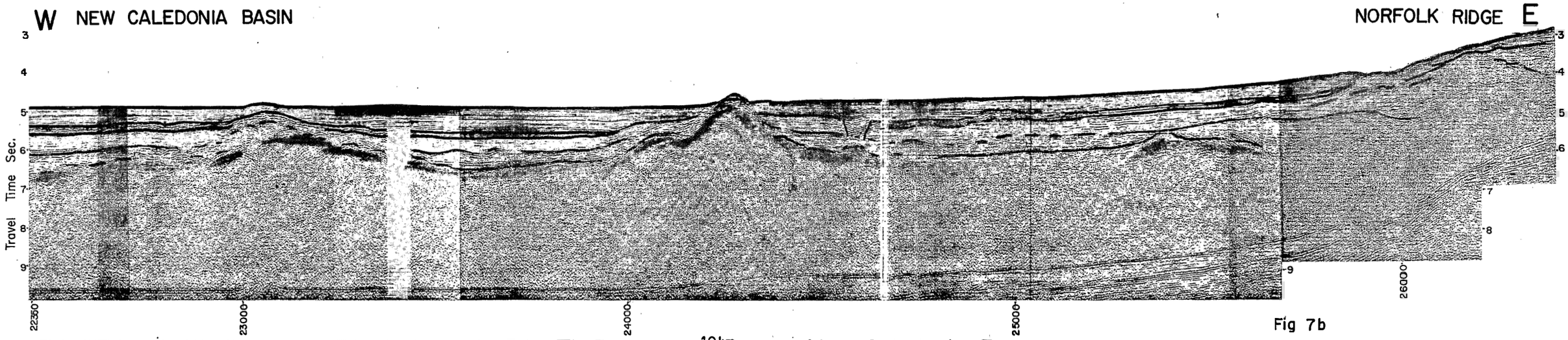


Fig 7b

IFP-CEPM-ORSTOM AUSTRADEC 206 PROFILE — 10km — New Caledonia Basin (Central · Part)

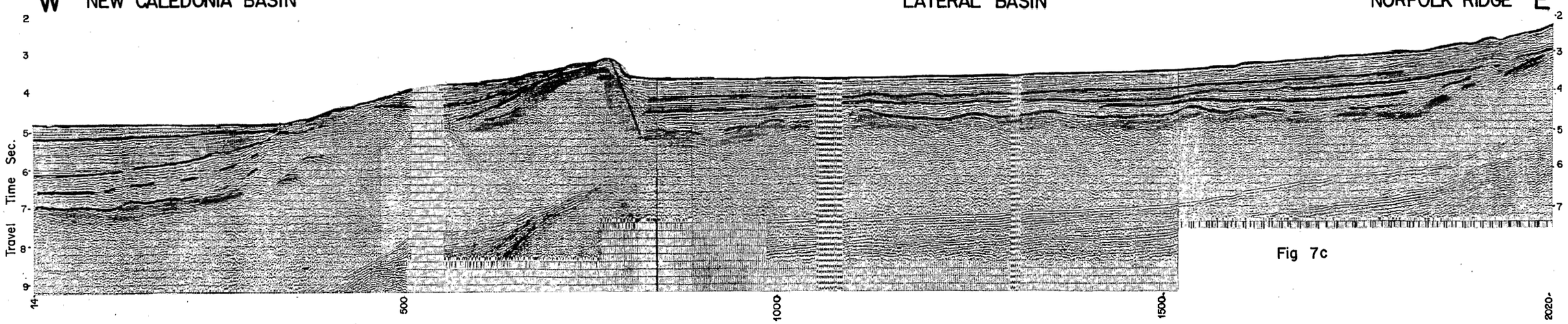
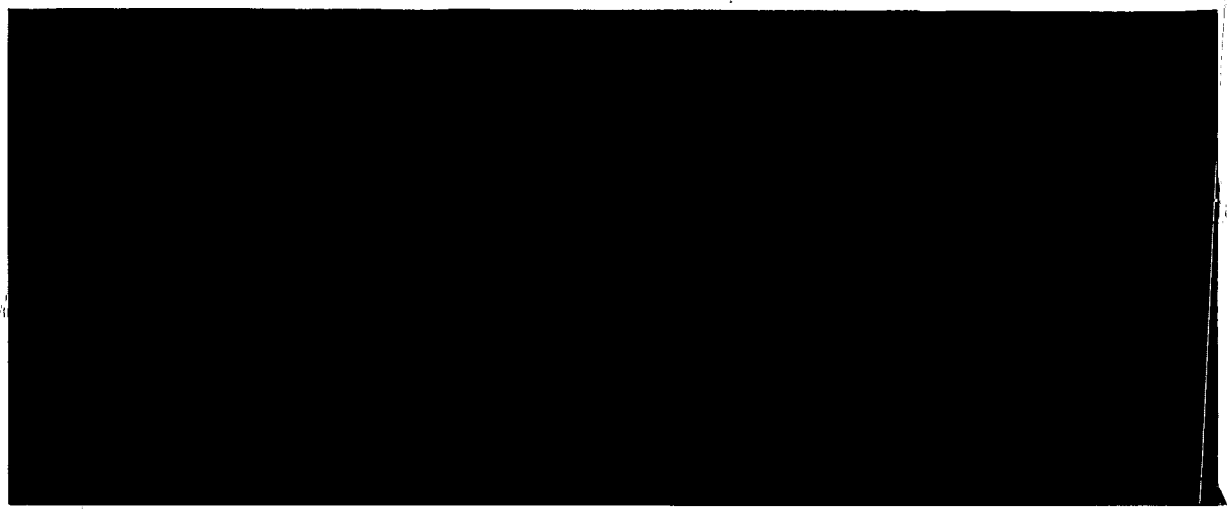


Fig 7c

IFP-CEPM-ORSTOM AUSTRADEC 103 PROFILE — 10km — Norfolk Ridge - New Caledonia Basin Area (NORTHERN EXTREMITY)



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GEODYNAMICS IN SOUTH-WEST PACIFIC

GÉODYNAMIQUE DU SUD-OUEST PACIFIQUE

NOUMEA – NOUVELLE-CALÉDONIE
27 AOÛT-2 SEPTEMBRE 1976

Sous le patronage de
Office de la Recherche Scientifique et Technique Outre-Mer
Bureau de Recherches Géologiques et Minières
Institut Français du Pétrole
Inter-Union Commission on Geodynamics.

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