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SEISMIC TRAVERSES ACROSS THE NORTHERN LORD HOWE RISE AND COMPARISON WITH THE SOUTHERN PART (SOUTH-WEST PACIFIC)

J. LAUNAY [1], J. DUPONT [1], A. LAPOUILLE [1], C. RAVENNE [2]
and C.E. de BROIN [3]

The Lord Howe rise is a major structural feature in the South West Pacific; excepting Lord Howe Island, it is completely submerged and spreads along about 2 000 km between the 21° S to the 37° S where it is adjacent to the New-Zealand continental shelf by the means of the Challenger Plateau.

The Austradec cruises supported by ORSTOM, IFP, SNPA, CFP and ELF-ERAP and carried out thanks the oceanographic research vessel of CNEXO permit to survey four seismic profiles (fig.1) across the northern Lord Howe Rise. Using as a sound source an IFP Flexi-choc, the seismic profiles were digitally tape recorded with a four thousand feet long twelve trace streamer and thus some records were processed.

PREVIOUS WORKS

The first informations about the Lord Howe Rise were given by Houtz et al (1967) and Van der Linden (1967) dealing with the morphology, the trend of the guyots and the age of the seamounts (upper cretaceous to middle tertiary). Standard in 1963 suggested the age of upper Tertiary to the more ancient basalts in the Lord Howe Island and Pliopleistocene for the more recent. Van der Linden (1970) shows up a subsidence of the rise several hundred meters deep and proposes the opening of the Tasman Sea on using the Dampier ridge as a spreading axis and the depression along the eastern Australian coast as a trench. Ringis (1972) resumes this point in stating with more accuracy the position of the fossil spreading axis directed at 330° and with an age within 80 to 60 M.y., and shifted by most of the fractures. After the Nova cruise, Solomon and Biehler (1969), Shor et al (1971) brought the first contributions on the crustal characteristics. They deduce a thickness of 25 km which involves for the crust a continental character equal to Australia. More recently Daniel and Dupont (1973) have compiled the recorded refraction data covering all the South West Pacific, and have established a chart summarizing the different layers with velocities and their thicknesses; the main part of the crust is formed with a layer of velocity 6 km/sec which can be compared with that of the Australian continental crust of the Queensland plateau; the oceanic layer at 6,8 km/sec is present beneath all the rise. After Woodward and Hunt (1971) the gravity measurements reveal a thickness from 0,5 to 1 km of sediments on the rise and its flanks. The heat flow measurements surveyed by Sclater et al (1972) spread from 4 to 100 HFU, but far too few to be significative.

The more recent data are provided by results given by the drillings 207 and 208 of the leg 21 (Burns, Andrews et al 1973). The 208 drill located in the North Lord Howe rise got through 594 m deep under 1 545 m of water depth. Two units have been surveyed, separated by a discontinuity between the mid Eocene and the upper Oligocene. That drill has reached the upper Cretaceous at the end of the coring. The 207 drill is located in the southern part of the rise : it has got, under 1 389 m of water depth, through 513 m of sediments which have been divided into five units. Between the

(1) Office de la Recherche Scientifique et Technique Outre-Mer, B.P. A5, Noumea Cedex, New Caledonia
(2) Institut Français du Pétrole, 1 et 4 avenue de Bois-Préau, 92502 Rueil-Malmaison, France
(3) Société Nationale Elf Aquitaine (Production), 26 avenue des Lilas, 64001 Pau, France

units 1 and 2, the stratigraphic lack is found but much more important : the upper Eocene, the Oligocene and the lower Miocene are lacking; the unit 3 is of maestrichtian age, the units 4 and 5 are tuffs and rhyolitic flows, those latter dated of 92 M.y. (Van der Lingen,1973). In fact all the drills made during the leg 21, have permitted Burns and Andrews (1973) to bring out the following conclusions on the West Pacific area : a subsidence took its origin during the lower Coenozoïc and ended during the Eocene, at the present depth : no tectonic traces were even found during the upper Coenozoïc : flora and fauna of the Paleogene are those of temperate area when those of the Neogene are tropical which improve the concept of a drift to the North of the western province since the separation of Australia from the Antarctic, say the mid Eocene. The stratigraphic lack shown in the province would not be due to the tectonics but to bottom currents. Those currents would have changed in direction and intensity during the opening of the Antarctic.

The last published studies on the Lord Howe rise follow up the surveys supported financially by the French Oil Companies (Dubois et al,1974) and by the Mobil Oil Corporation (Bentz, 1974).

MORPHOLOGY

From the morphological point of view,(see fig. 1 and 2), the Lord Howe rise looks like a wide bulge with a broad curvature mainly directed North South. In its northern part, it is directed North South along 1400 km, then at the level of the 33rd parallel South, the rise turns to the South East along 600 km approximately. Its width is maximal (400 km) near the 31st parallel South, but is narrowing at both its extremities and particularly to the North where the rise takes its origin South of the Lans Downe Bank. Its eastern boundary are the Fairway and New Caledonia basins; the Lord Howe basin, the alignment of Lord Howe guyots, the Dampier ridge and the Tasman Sea are its western boundary. Lord Howe Island lying approximately 31° South and 159° East is on a guyot of the eastern trend. The rise presents a flat low relief top, the central plateau altitude is nearly constant under a water depth of 1 200 to 1 500 m. The flanks of the rise are nearly symetrical with quite a gentle slope, excepting some places on the western flank where some guyots model the topography, and South East where even slumps can be found (Bentz, 1974).

The results of the seismic reflection lead us to discern two groups :

-the sedimentary cover, say the area involved between the basement and the rise surface; our recordings show that it is formed with, either "transparent" units, or series with many reflectors.

- The basement; it is an acoustic basement, say a limit of penetration due to volcanic flows or to hard-grounds.

THE SEDIMENTARY COVER

The thickness of the sedimentary cover varies in a sensible way. It looks the thinnest at the top of the rise, this top being in axial position or shifted to the eastern border by the dissymmetry of the rise basement. The sedimentary cover is thickening from the centre to the flanks: it increases from 0.3 s.t.w.t. (two way travel) on the axis to more than 2 seconds on the flanks or in the narrow basins modeling the basement and where more and more ancient series are observed, with disconformities between them.

The whole sedimentary cover may be divided into two unconformable units :

- the lower unit, more ancient, unconformable on the acoustic basement is well developed: it constitutes the essential of the filling up of the reliefs and may be divided into two series unconformable one on the other. Those disconformities belonging to the lower unit, emphasizes that, at the moment of the deposit, the rise basement was affected by tectonic movements by block faulting; the limit between these both ancient series is not always visible, but when it is clear, it is associated with a neat angular disconformity between both the series.

- Above, the recent unit is subhorizontal and in disconformity with the ancient series. Its consists in a transparent horizon (see fig. 3) which indicates a quiet and homogeneous sedimentation : calcareous fossil ooze; that horizon is frequently divided into two by a reflector or a set of reflectors.

The Austradec 101 and 205a profiles are particularly interesting in the cover observation because of their location on JOIDES drill 208 (see fig.3) the location of the sedimentary lack from mid-Eocene to upper Oligocene evidenced through the drilled core microfauna, is marked by a strong reflector associated with the boundary between the two main units.

The basement was not reached by the core drilling, as shown by the figure 3, the upper Maestrichtian was found at 594 m deep; the acoustic basement is found at about 200 to 400 milliseconds deeper, one can suppose the overlying sediments to be cretaceous in age ; the drilling being located above a bump of the basement, one can deduce that the mid and lower Eocene is rapidly thickening in the basin; the stratigraphic lacks may be due to bottom currents which, either erode a preexisting sedimentation on the rise and fill the basins up with sediments with formations of hard grounds on the tops, or rather prevent any sedimentation.

BASEMENT AND MAGNETIC FEATURE OF THE RISE

We assume the basement as the unit located beneath the last reflector, separated from the sedimentary cover by the major disconformity. On our records, it corresponds generally with the penetration limit, and may be due to interstratified volcanic flows (see fig.2 Aus. 101 - 206 - 205b) or to hard grounds; on the eastern flank one can notice the presence of horst which can be assumed as an uplift of the basement.

The seismic sections show that this rise basement has been highly tectonized with formation of horst, graben, many fractures and probably folds. Provided the age of lower Cretaceous of the sedimentary series immediately overlying, and by analogy with the effect of the cimmerian and neo cimmerian phases well known in New Caledonia (Avias, 1959, Routhier, 1953, Gonord, 1968 and 1970, Guillon, 1975, Guérangé et al 1975), it is allowed to attribute Jurassic or Permotrias in age to this basement, its sedimentary and volcano sedimentary make-up seems to be confirmed by the presence of some inner more or less organized reflectors.

The Lord Howe Rise is characterized by a high magnetic relief with lot of variations of short and long periods and whose amplitudes are generally high. The major feature is in the positive variations with long wavelengths, approximately a hundred kilometers, correlatable on long distances with respect to the general topographic trend of the rise. They indicate important heterogeneities in the deep substratum; their amplitude tending to decrease to the South, one can deduce a thrusting of the basement in that direction.

Associated with those high variations, shorter wavelengths variations are superimposed whose amplitudes remain high too, indicating, as for them, an important heterogeneity of surface rocks.

Magnetically the Lord Howe Rise takes its origin South of the Lans Downe Bank, say at 22° S. As a matter of fact, a reduction to the pole of the magnetic anomalies of the profiles Aus 105 (assuming the remanent magnetization to be equal to that of the ambiant field) shows off a general displacement of the anomalies to the East. The Lans Downe Bank is in fact the extension of the Fairway basin uplifted to sort of perched basin looking like a horst. Its eastern buttress characterized by the anomaly more than 1 000 gammas represents, as for it, the origin of the Fairway rise.

The numerous magnetic variations of that broad submarine chain are due to the unhomogeneous nature of the continental basement and to its width (in opposition to the other neighbouring rises, Dampier, Fairway, Three Kings).

On the assumption of the surveyed magnetics, the rise would be divided into three juxtaposed longitudinal elements as shown in the following :

a) The more regular and marked magnetic anomalies in the eastern part indicate a less disturbed basement. Those apparently regular anomalies may be disturbed by volcanic intrusions. The eastern zone, the higher and the less disturbed, may be considered, with respect to its morphology and its magnetics, as the main part of the Lord Howe group which the other parts are adjoined. The anomalies being better marked on that part than on the western part induces the basement dipping to the west.

b) The middle part is getting narrower to the South, as far as the western part directed NNW-SSE is coming nearer to the eastern part directed N.S. between 26° and 29° South.

c) As for the western part, it seems after the correlations between the magnetic anomalies that it blocks up against the 159° East guyot trend.

Thence we can assume that the Lord Howe rise may be parted into several longitudinal structural elements, in agreement with the morphological conclusions of Van der Linden (1969) and Conolly (1963), which divided the rise into two longitudinal parts.

The existence of an elongated basin about 160° E, North to 24° S could be caused by vertical movements marked by faults directed NNW - SSE which have cut the western part of the rise into blocks giving then horsts and grabens.(Ringis, 1972).

COMPARISON WITH THE SOUTH OF THE RISE

The South of the Lord Howe rise has been oversurveyed by the Mobil Oil Corporation which in 1972 recorded some seismic and magnetic profiles, whose results were published by Bentz (1974) (see fig. 1 and 4) and previous JOIDES drillings North and South allow the comparison between those two parts to be made:

a) The sedimentary cover thickness above the acoustic basement appears relatively constant North to South. Though the 207 and 208 drills bring out a difference in the duration of the lack, Bentz (1974), explains it as due to very located variations of the topography before the lack and a differential subsidence after the lack.

b) The Maestrichtian represented North by calcareous ooze indicates a deep water facies while South the same aged terrigeneous clays induce an epicontinental sedimentation.

c) The drilled rhyolites South and dated of 94 M.y. (Van der Lingen 1973) have been emitted with tuffs and lapilli which would indicate a sub-aerial way of flowing. South as well as North, we find again magnetic anomalies at the level of paleogene and neogene rocks which would imply the presence of interstratified volcanic materials; the Mobil profiles (see fig.4) show volcanic extrusions in great number which Bentz has interpreted as dykes rather than volcanoes.

During Georstom III cruise in November 1975, we dredged on the flank of the main extrusive massif as shown on the 112 and 109 Mobil sections and which higher crest is 750 m deep (see fig.4). Nearly 50 kg of rocks were recovered on board, in which 20 % were basalts and gabbros, the remainder being a mixture of hyaloclastic "breccias" and of biomicrites with a high rate of foraminiferas and coral debris.

a) The basalt (sample 357 D_1) is highly altered and present a zoning which can be developed on as following :

- an inner zone with a grey blackish color presenting many vesicles filled with calcite associated with different transformation products (zeolites). The olivine corroded and altered into ferruginous products from phenocrysts. The clinopyroxene augite or diopside is found in microcrystalline. As for the amorphous matrix, it contains very fine microlites of plagioclases. Above, that rock is getting more and more vitrous while the vesicles no longer show filling and we reach progressively a black, compact, which is sideromelane.

- A middle part with yellow palagonites.

- An upper part formed with typical hyaloclastite showing debris of reddish yellow palagonite wrapped into calcite and bordered at its basement by massive calcite.

One can notice that this rock contains intrusions of a centimetrical scale probably composed of strongly altered gabbros associated with olivine and pyroxene.

In conclusion, this rock is a basalt with olivine, hardened during the submarine flow, with gabbroic inclusions, and strongly altered. The chemical analysis reproduced in the following table reveals an abnormally low content in silica. However the alkalines are numerous ant it is fitting to note the high loss by burning corresponding probably to the evacuation of the water from the zeolites.

	Basalt 357 D_1	Gabbro 357 D_4
$Si\ O_2$	34.22	44.63
$Al\ O_3$	9.56	20.79
$Fe_2\ O_3$	10.50	9.81
$Mg\ O$	10.54	4.42
$Ca\ O$	16.71	12.70
$Na_2\ O$	2.12	2.45
$K_2\ O$	1.22	0.23
$Ti\ O_2$	1.92	1.69
$P_2\ O_5$	1.00	0.08
Loss by burning at 110°	1.27	0.31
... from 110° to 1050°	9.37	1.61
	98.43	98.72

b) The gabbros (samples 357 D_4). They look like small blunt blocks of gabbros (the olivine marking the linear foliation), one can observe into it plagioclase (labrador) pyroxene (diallage), olivine and also opaque minerals such as the magnetites. The state of alteration involves the chemical analysis to be undoubtedly very significative, but however it appears that we could connect those gabbros with alkalin rocks with olivine.

The biomicrite includes two types of biological material well separated; on one hand planktonic foraminifera in deep water, on the other hand coral debris; those coral formations were possible only in shallow water and on the top of the massif; those dead corals were scattered along the slope and the diagenesis of the rock occurred in association with the foraminifera. The main types of foraminifera found there are the Globorotalia and Orbulina, we have to assume that since the mid-Miocene base at the earliest, at least 600 m subsidence occurred. That fact is to be compared with the results of dredgings made North to the Norfolk Ridge, close to New Caledonia (Daniel et al 1976) where an at least 400 m subsidence has been emphasized since Miocene or at the latest, at upper Pliocene.

The dredging on the Lord Howe Rise suggests that the general subsidence described by Bentz had not reached 1 500 m at the Paleogene, it could have been limited to approximately 500 m deep, which would permit coral growth on the top of the massif and the deposit of planktonic foraminifera at its base. Then after the mid-Miocene, the subsidence would have resumed to reach the present depth.

CONCLUSION

As a general conclusion, the Lord Howe Rise can be assumed as a continental structure. The basement evidenced by the seismic lines could be permo-triassic in age and be formed of volcano-sedimentary rocks similar to those known in New Caledonia and in New Zealand, which are supposed to form the Norfolk ridge basement (Dupont et al 1975). The sedimentary cover is important on the flanks and in the basins, for it can be more than 2 s.t. w.t. The dredging made in the South of Lord Howe rise revealed the basaltic and gabbroïc nature of one of the dykes described by Bentz 1974. Another result is that the biomicrites emphasizes an about 1 200 m deep subsidence, since the Paleogene. Finally on the base of the eastly best marked magnetic anomalies we can derive the rise eastern border to be a structural unit directed NW - SE which can be compared with the guyot trends.

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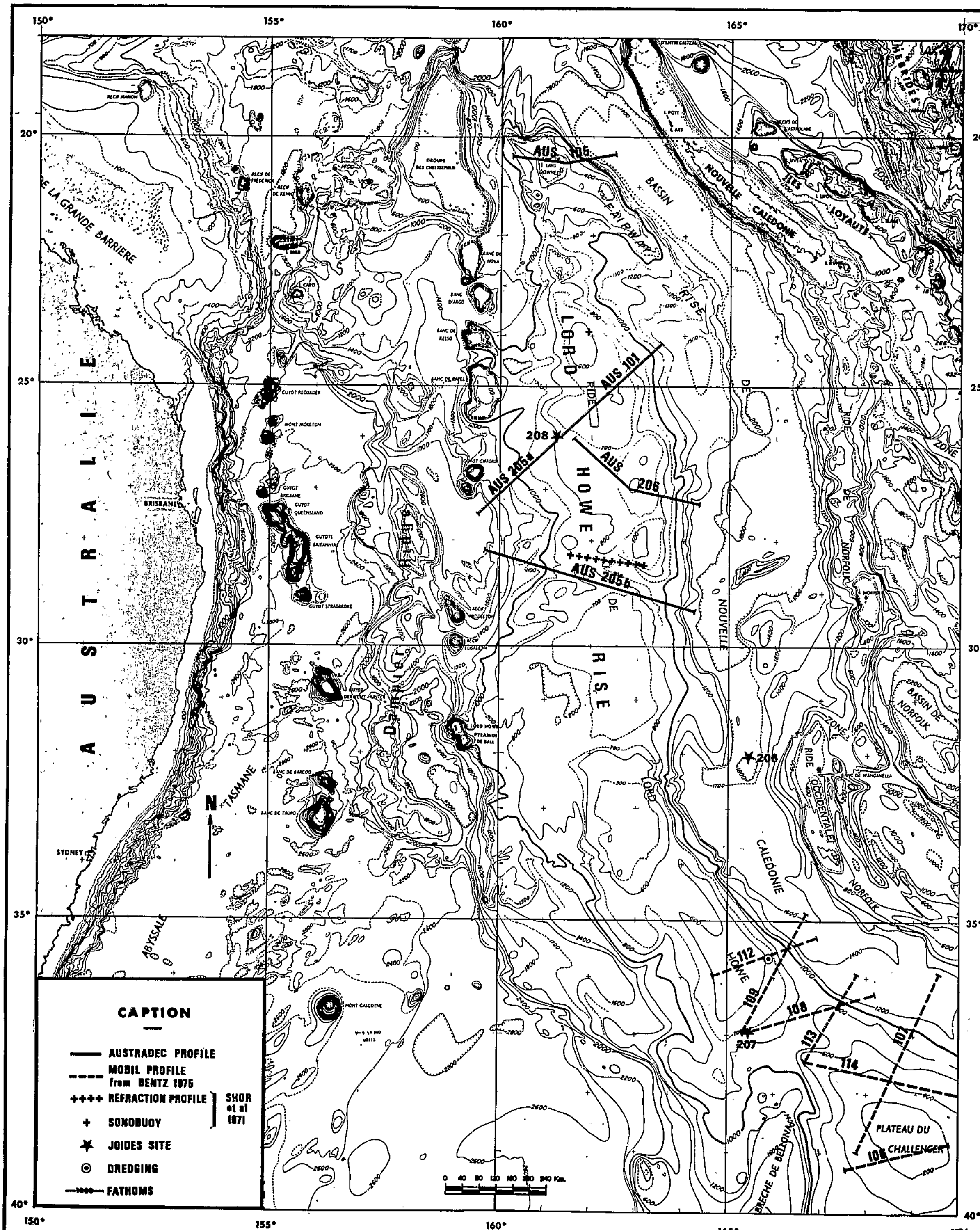


FIG. 1 - Location of AUSTRADEC and MOBIL'S Marine Reconnaissance

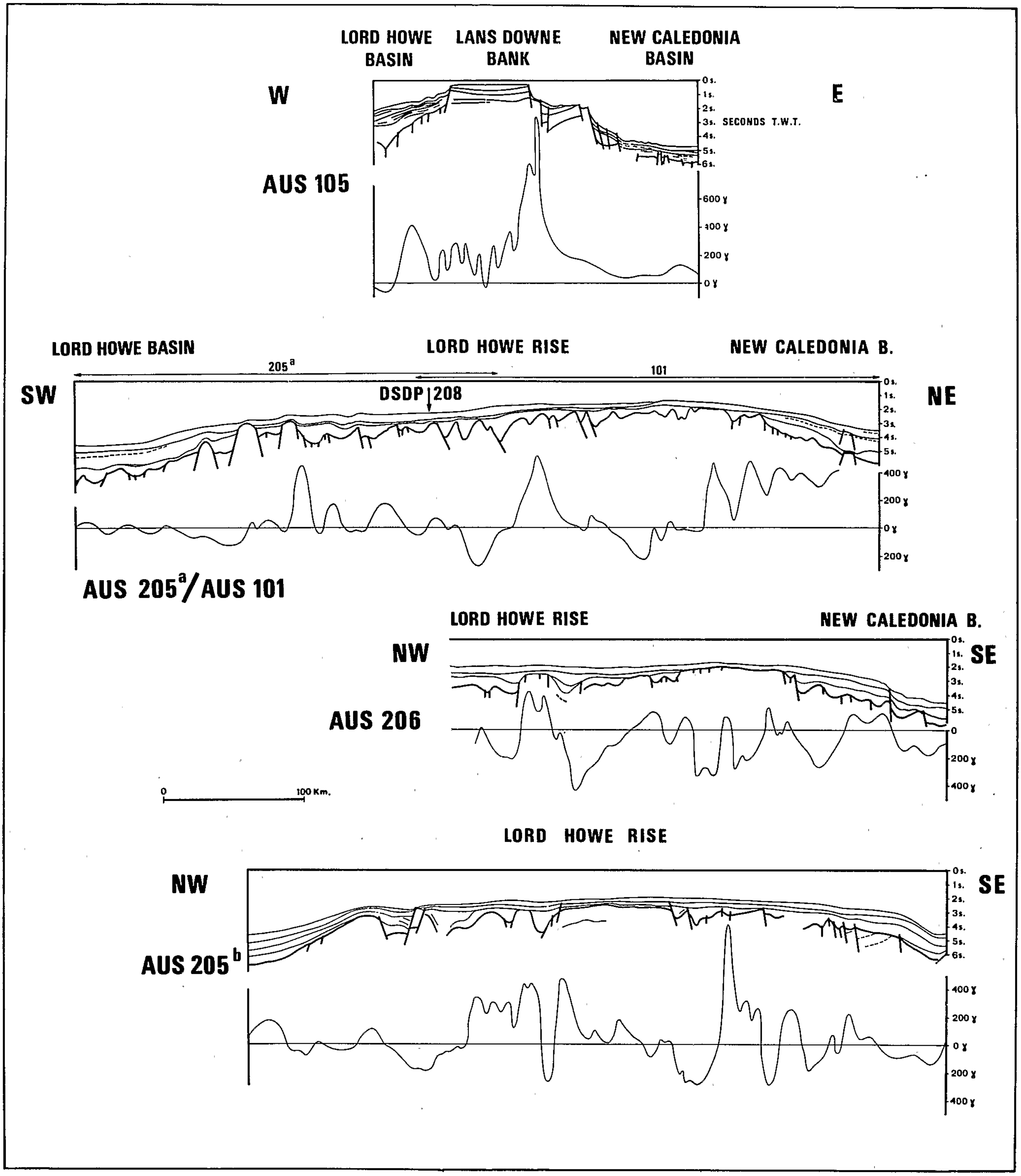
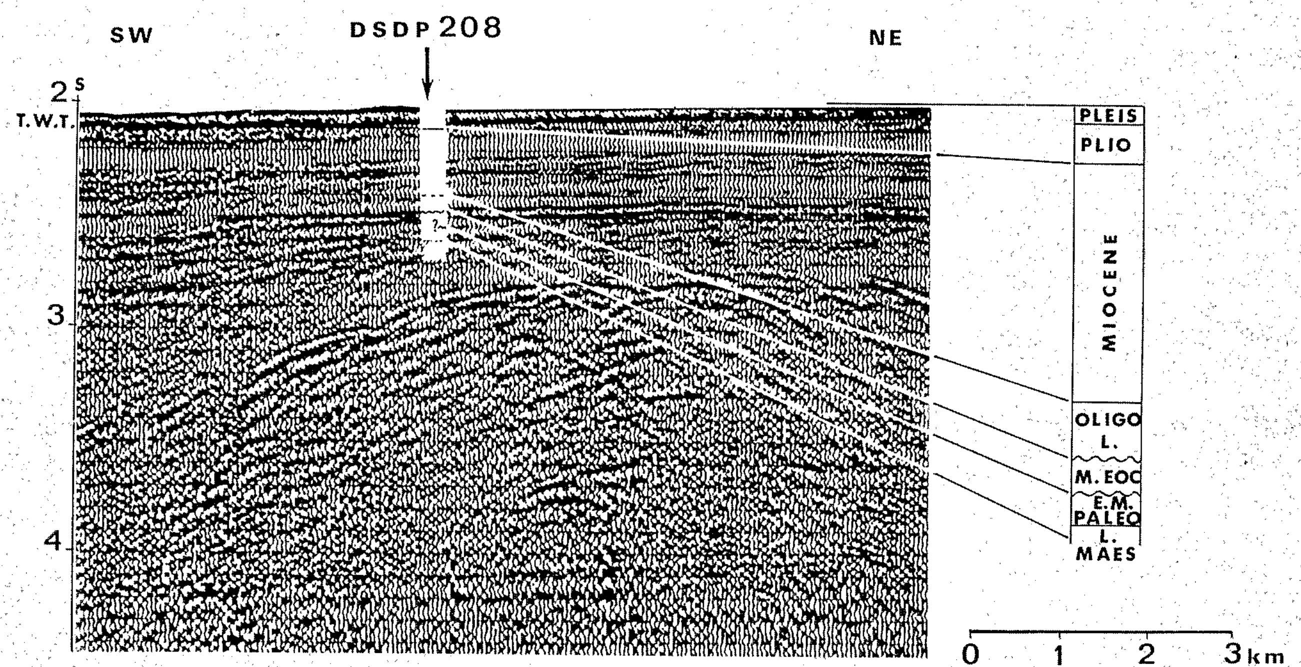


FIG. 2 - AUSTRADEC interpreted lines (seismic and magnetic anomalies)



LOCATION OF DSDP 208 ON AUS 101 PROFILE

Fig. 3

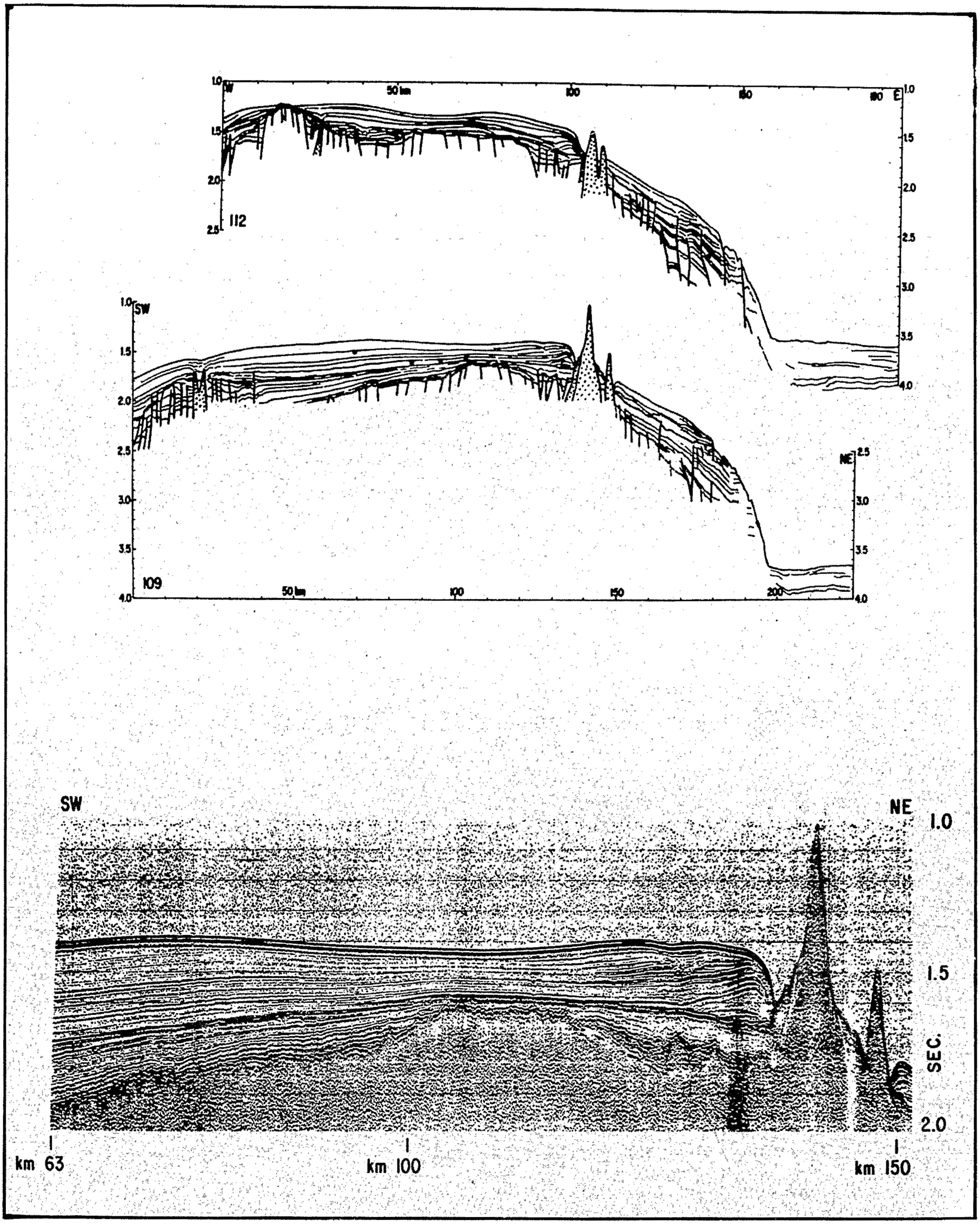


FIG 4. - MOBIL interpreted lines and detail of line 109, showing submarine volcanism. (from Bentz 1974).

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