STRUCTURE AND HISTORY OF LOYALTY BASIN (South Pacific)

by

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D R A F T

INTRODUCTION

Within a continuing, cooperative programme between the Office de la Recherche Scientifique et Technique Outre-Mer (O.R.S.T.O.M.) in Noumea, and the University of New South Wales, Australia, several continuous seismic reflection profiles were obtained across the Loyalty Basin, using a 650 cc (40 cu.in.) airgun seismic source. Continuous bathymetric (P.D.R.) and total field magnetic profiles from a proton magnetometer were also recorded. The locations of the profiles are shown in Figure 1. They were recorded during 1971 from H.M.A.S. Kimbla on cruises K3/71 and K4/71, and from O.S. Coriolis on cruise C1/1971.

Within the overall study, designed to contribute to an improved understanding of the geodynamic history of the Southwest Pacific, the purpose of these particular profiles was to study the Loyalty Basin, and its relation to New Caledonia to the southwest and to the Loyalty Island archipelago to the northeast. These linear, parallel structural elements lie within the northwestern margin of the Indo-Australian Plate, close to the present plate boundary at the New Hebrides Trench where active subduction beneath the Pacific Plate is currently occurring. They also lie at the northeast limit of a system of ridges and basins which extend back to the Australian continent with morphological trends generally paralleling the Australian continental margin.

This system of ridges and basins has the appearance of continental to intermediate crustal blocks rifted from the Australian continental margin. In the case of the Tasman Sea Basin, Ringis (1972) and Hayes and Ringis (1973) have shown the Lord Howe Rise to have been rifted from Australia and displaced by a seafloor spreading accretion process at a now extinct mid-ocean ridge, between 80 and 60 m.y.b.p. The origin of the remaining basins and ridges in this area, and the ridges, plateaus and basins in the general area of this plate margin is still controversial. Several hypotheses have been advanced to explain specific or general evolution of such features within the area. These include the evolution of complex arc systems (Gaze, 1963, Dubois, 1969), arc migration and the development of marginal basins (Karig, 1971 ; Packham and Falvey 1971), and the creation of marginal basins by expansion due to second order adjustments at the limits of plates (Andrews et al., 1973a)

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In the case of the Loyalty Basin and Loyalty Ridge, however, the situation is further complicated by a hypothesis which proposes the existence of a fossil trench system at a position immediately to the northeast of New Caledonia. This was proposed by Coan in 1953, and the presence of a subduction zone in this position during Eocene-Upper Oligocene time, has been supported by seismological studies of Dubois (1969, 1971) and heat flow studies of McDonald et al. (1973). The inferred presence of this previous subduction zone implies that the Loyalty Island chain may represent the ancient andesitic volcanic arc above the old Benioff zone. This area of study is therefore one of particular interest within this broad area of significant geodynamic activity.

GEOLOGICAL BACKGROUND

Regional setting

From northeast to southwest across the general area (figure 1), the major structural features are :

(i) The New Hebrides Trench which strikes at 150° E between latitudes 11° S and 22° S where it bends sharply to acquire an easterly trend.

(ii) The North Loyalty Basin which is triangular in shape and lies between this trench and the Loyalty Islands.

(iii) The Loyalty Ridge which is largely submarine with its highest points forming the Loyalty Islands and supporting raised coral atolls.

(iv) The Loyalty Basin.

(v) The island of New Caledonia, the southeastern extension of which is essentially continuous with the northern part of the Norfolk Ridge which has a north-south trend in that area.

(vi) The New Caledonia Basin which separates the New Caledonia - Norfolk Ridge features from the Lord Howe Rise.

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Crustal thickness and heat flow

The variations in crustal thickness in this region underline its complexity. Seismological determinations of Dubois (1969) show the crust to reach a thickness of 35 km in New Caledonia and 17 km in the Loyalty Islands at Maré Island. Marine seismic refraction profiles recorded during the Nova cruises (Shor et al. 1971) show the following crustal thicknesses, with the depths to mantle shown in brackets :

12 (14) and 18 (20) km for the Loyalty Basin, 20 (21) and 21 (21) for the Norfolk Ridge immediately to the South of New Caledonia, 9 (13) and 11 (14) km for the New Caledonia Basin just to the southwest of New Caledonia, and 13 (17) and 7 (10) km in the New Caledonia Basin further to the south. On the Lord Howe Rise thicknesses of 16 (18) and 28 (29) km were calculated, while in the South Fiji Basin to the east of the Norfolk Ridge, calculated thicknesses were 11 (15) and 8 (12) km in the northeast and 6 (10) and 8 (13) km in the south central part of the basin. No crustal measurements have been made in the North Loyalty Basin.

The heat flow measurements of McDonald et al. (1973) show normal values for the Loyalty Basin of 1 to 2 HFU, whereas to the east of the New Hebrides Trench on the North Fiji Plateau, high values of up to 3 HFU were obtained.

Results of Deep Sea Drilling Project

Several holes have been drilled into the sea floor within the area of the Southwest Pacific during legs 21 and 30 of the Deep Sea Drilling Project. The results obtained have been reported by Burns et al. (1972), Andrews et al. (1973a and 1973b) and Van der Linden (1975), and have led Andrews et al (1973a) to divide the region into eastern and western provinces.

The western province consists essentially of the Lord Howe Rise, the New Caledonia Basin and the Norfolk Ridge. While the oldest sediments present in this province are of Upper Cretaceous age, its essential characteristic is the lack of sedimentation between the Upper Eocene and Middle Oligocene. The duration of this break in sedimentation is variable over the area and greatest on the Lord Howe Rise. It is generally attributed to changes in the circulation of ocean currents resulting from the initial separation of Australia from Antarctica in the Eocene some 55 m.y.b.p.

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The eastern province consists essentially of the South Fiji Basin, which is supposed to have come into existence in the Oligocene, and the North Loyalty Basin which probably formed in the Lower Eocene. The regional lack of Upper Eocene/Middle Oligocene sedimentation characteristic of the western province, does not occur in this province, showing it to have been under different influences to the former.

Geology of New Caledonia

New Caledonia is an island of 400 km in length and 45 km in width, with a surface area of 18,000 km^2. It is flanked to both the west and the east by barrier reefs that extend some 200 km to the north of the most northern tip of the island. To the south, New Caledonia extends into the submarine Norfolk Ridge with which it appears continuous from seismological evidence (Dubois et al., 1971), as well as in morphological expression.

The oldest known formation in New Caledonia is a polycolour tuff which has been attributed to Permian age by Avias (1953) and Routhier (1953). From the Permian to the Upper Eocene, the rocks observed are pyroclastic and clastic sediments (greywackes, sandstones, pelites, argillites and flysch), accumulated in what has been called the Melanesian Trench. A number of different geotectonic phases have been observed on the island, the last of which was an alpine type orogeny which began subsequent to the deposits of Eocene flysch (Genard, 1970). The peridotites and basalts which occur extensively over the island, appear to represent the inverse flank of a recumbent fold (Guillon, 1972) which was emplaced at the end of the major Alpine type orogenesis, probably in Oligocene time (Guillon & Routhier, 1971). This episode represents the last orogenic event to which the island was subjected, after which only the effects of epirogenic movements have been observed. The latter are represented by the presence of peneplains and successive terraces (Davis, 1925 ; Trescases, 1969). (The peridotites which cover some 7,000 km^2 of the island, may have covered a much larger area (Guillon and Routhier, 1971). They have, however, been submitted to considerable erosion, mainly chemical in nature, the residual lateritic deposits of which may be observed in situ or redistributed along the slopes, peneplains and terraces.

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Geology of the Loyalty Island Archipelago

The Loyalty Island Archipelago consists of coral atolls, which formed during the Pleistocene (Chevalier, 1968), as cappings on the summits of a submarine ridge during a period of subsidence. These subsequently emerged to form the Loyalty Islands (Dubois et al. 1973). The only observed basaltic volcanics protrude through basement of the atolls is on Mare Island where on these summital basaltic the bottom of an old lagoon. Potassium/argon measurements made formations give an age of 10 my (Guillon and Recy, in preparation), which probably represents the last episode of volcanic activity of the submarine ridge. This ridge extends both to the north and south of the actual Archipelago. Neither the age of the beginning of this volcanic activity, nor the number of phases of volcanism is known at this time. The structure of the ridge and the relative contributions of volcanic, volcanoclastic and sedimentary rocks to the formation of the ridge are also unknown.

MORPHOLOGY

The bathymetric map published by the Scripps Institution of Oceanography (1971) for the Southwest Pacific, shows a depression between New Caledonia and the Loyalty Islands. This is elongated in a direction northwest-southeast between the latitudes of 20° and 23° S, and exceeds a depth of 2 150 m. The bathymetric profiles from the present study are shown in figures 1 and 2, and provide some further information on the morphology and extent of this basin.

Transverse profile

The most complete profile across the basin is profile 7 which passes immediately to the southeast of New Caledonia and the Isle of Pines. From southwest to northeast on this profile (fig. 2), there may be observed the extension of New Caledonia to the south of the Isle of Pines, the Loyalty Basin, the Loyalty Ridge, and the downward slope to the New Hebrides Trench.

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The Loyalty Basin appears as a flat depression with a maximum depth of 2 150 m which is remarkably constant over a distance of about 40 km. In general appearance, there is little assymetry between the western and eastern flanks of the basin. In detail, however, two steps in the profile may be observed on the western flank. The first, between depths of 500 and 1 000 m, connects the plateau which forms the southern extension of New Caledonia and the Isle of Pines, to an area of gentler slope which extends down to 1 800 m. At this level, the second rapid decrease or step in the profile occurs which passes directly to the level floor of the basin. Towards the eastern flank, the floor of the basin progressively rises until a single sharp step occurs at the margin of the Loyalty Ridge. Variations which occur in morphology across the basin both to the north and south of profile F, are also shown in fig. 2. To the north of profile F, the profiles A, B, C, D and E are incomplete, but show the western edge of the basin to slope up towards the margin of New Caledonia. In the east, the limit of the basin is constituted by the Loyalty Ridge. However, depending on the position of the profiles relative to the various islands of the Loyalty group, they show different characteristics. For example, on profile E to the southeast of Mare Island, there occurs a plateau at a depth of 1 500 m. However, on profile A to the north, two seperate ridges occur, seperated by a small basin which appears to lie within the ridge itself.

From the bathymetric map, there appears to be a discontinuity in the ridge beyond Astrolabe Reef. However, the profile of Coriolis/1966, which is shown in Figure 3, passes well to the northwest of this reef and shows the ridge structure to continue with a relief of 1 650 m above the sea floor between the latitudes of 19° and 20° S. This ridge appears to persist as far north as the Petrie Reef at a latitude of about 18° 30' S, and probably extends even further to the north.

To the east of the Loyalty Ridge, the sea floor slopes downwards towards the New Hebrides Trench but shows considerable variation in the different profiles. The slope is more regular on profile E than those further to the north, particularly on profiles A and C where distinct steps in the profiles occur.

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In the south on profiles G, H, I and J, the eastern limit of the morphological basin is clearly marked by a ridge whose direction tends to the south without quite reaching the north-south trend of the Norfolk Ridge. From the bathymetry, there appears to be no reason why this feature does not represent the southern extension of the Loyalty Ridge.

On profiles G and H, there occurs a rise which forms the western limit of the basin. This drastically narrows the basin from a width of 90 km on the adjacent northern profile F to a width of 47 km on these profiles. This narrowing coincides with the bending in direction towards the south.

With the change to an easterly trend by the New Hebrides Trench to the southeast of profile H, neither of the more southern profiles, I and J, display the downward slope towards this trench, but show the beginnings of the regular structure of the sea floor which characterises the South Fiji Basin.

<u>Longitudinal profile</u>

In order to trace the longitudinal profile of the basin, a synthetic profile has been constructed from the profile [illegible] and the maximum depth points of the transverse profiles of the present survey. This is shown in Fig. 4 from which it may be seen that there is a step [illegible] level of Astrolabe Reef which raises the seafloor of the basin to a depth of 2 300 m. This depth remains constant between profiles [illegible] decreases to 1 500 m at profile G before increasing again towards [illegible].

In the general morphology [illegible] as an elongated depression with a widening or bulge at the [illegible] where it bends towards the south. [illegible] the basin as defined on the morphology from the present synthetic profile.

SEISMIC STRUCTURE

In this section will be described the geological structure across the basin, its southern extent, its western margin against New Caledonia, and its eastern margin against the Loyalty Ridge.

Geological structure across the Loyalty Basin

The seismic reflection profiles across the Loyalty Basin show that the deep structure of the basin is more accentuated than its morphological expression. The sediment cover over accoustic basement is very thin at the edges of the basin but at the centre, the depth to basement was greater than could be observed despite a sub-bottom penetration in excess of 2.5 sec on some profiles.

As in the discussion on morphology, since the northern profiles A, B, C, D and E are incomplete, the main features of the seismic section will be described from the continuous section across the basin obtained on profile F (see fig. 5). On defining the limits of the basin, we take the western limit as the prominent step against which about the almost horizontally layered sediments of the basin. The eastern limit is taken as the steep boundary between the basin sediments and the Loyalty Ridge.

The most remarkable feature of the basin is its asymmetry. The total thickness of sediments within the basin is greater on the western side where they have a much more regular aspect than those to the east. On the eastern side, the sediments are raised and folded.

Within the sedimentary section, the seismic profiles show three disconformities, allowing four main units to be defined. These are shown in Figure 5 as I, II, III and IV.

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The upper formation (I) has a maximum thickness corresponding to a two-way reflection time of 1.1 sec. This occurs in the deepest part of the morphological basin and is displaced towards the western margin of the geological basin as defined above. Towards the west, the numerous reflectors within this formation are nearly horizontal. Towards the east, where the thickness is much less (0.2 to 0.3 sec two-way time), only the first group of reflections may be observed due to the length of the bubble pulse sequence of the reflected signals. The lower boundary of this formation is, however, readily observed over the whole width of the basin. As with the other formations, these sediments over the eastern part of the basin show folding.

The second formation (II) has a maximum thickness corresponding to a two-way reflection time of 0.9 sec. This occurs at the point where base of the formation begins to rise towards the east, and lies considerably further to the east than the maximum sediment accumulation in formation I. On the western part of the basin, the formation thins gradually to the west and appears to pinch out at the western margin of the basin. To the east, the layer becomes increasingly deformed and thins abruptly at the eastern margin near the Loyalty Ridge.

This implies that some uplift on the eastern side of the basin has occurred between the deposition of formation II and formation I, with the axis of sedimentation having migrated to the west during the deposition of the latter. The gradual lensing out to the west relative to the rapid thinning near the Loyalty Ridge to the east also implies that the main area of provenance of sediment during the deposition of formation II was the Loyalty Ridge.

Formation III is clearly marked over the whole width of the basin by the regularity of its upper reflector. At the western margin of the basin the layer pinches out rapidly against what appears to be basement which is labelled CI in Figure 5. To the east, the layer thins gradually and becomes increasingly deformed until it terminates rather abruptly against the Loyalty Ridge.

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The base of this layer is not observed in the centre of the basin. However, the rapid thickening of the layer from the western margin towards the centre and the comparable thicknesses on each side where the base of the layer is observed suggest (i) that the axis of sedimentation during the deposition of layer III was again further to the west than during the deposition of layer II, and (ii) that the provenance of sediments during the deposition of layer III was probably from both New Caledonia and the Loyalty Ridge, possibly with a greater contribution from the former.

Layer IV is only observed in the eastern part of the profile but may correspond to the basement on the western side shown as C1 on figure 5. Layer IV probably represents the basement in the eastern part of the basin.

The seismic refraction profile of Shor et al. ('67), which is located along the axis of the basin between profiles D and E, provides a model for comparison with results of the reflection profiles. Shor et al. found three layers which overlie a layer with a velocity of about 5.9 km/sec, which deepened northward along the axis of the basin. This velocity is high and is consistent with a crystalline or highly metamorphosed basement. The refraction velocities for the three overlying layers are given as 2.2 km/sec, which was assumed for the surface layer, 3.5 km/sec, and 5.2 km/sec. The first two velocities are representative of poorly consolidated and well consolidated sedimentary material respectively, and the last of limestone, partly metamorphosed or volcanic material.

Although some differences occur between the depth determinations to the interpreted layers in the refraction results and reflection profiles results using the velocities of Shor et al., it appears possible to correlate the two. The difference in calculated depths may result in part from the rather poor control on the travel-time curve of Shor et al. (their p 2569) at the southern of the refraction profile.

On this correlation, we assign layer IV as basement (the 5.9 km/sec layer) and layers I, II and III as sedimentary formations infilling the basin. The deepening of the basin to the northwest along the axis of the basin found by Shor et al is supported by an as yet unpublished heavy seismic reflection survey by Dubois et al. (in preparation). This shows that the total thickness of the first three formations increases in this direction to reach a two-way time of at least 4 sec. The above results have been combined into a longitudinal profile along the axis of the basin showing two-way reflection times their equivalent from the refraction survey (figure 6).

Geological structure along the Loyalty Basin

The northern limit of the basin, which appears from the Scripps bathymetric map to occur at the position of the d'Entrecasteaux Fracture Zone, is not covered by the present survey. On the south, the thickness of formation decreases considerably, having a two-way time of only 0.5 sec on profiles H and I. Formation II which is characterised by many internal reflectors, appears more variable in thickness but has also decreased at the level of profile I. Between profiles I and J there appears a very strong reflector at the base of formation II, which we interpret as basement with the rapid lensing out of formation III between profiles H and I.

All three sedimentary formations rise following a rise in the morphology of the surface at the level of profile G. Although the basement (layer IV) probably also follows this hump, it is not recorded on profiles G and H, and does not occur until profile I where it appears to be quite shallow.

From the above considerations, we place the southern limit of the geological Loyalty Basin at about the level of profile I. The northern limit of the basin remains undefined with the sedimentary fill within the basin thickening to the northwest over the area of survey.

Western margin of the Loyalty Basin

Profile F passes just to the south of the Isle of Pines on which the southernmost exposures of the peridotites of New Caledonia occur. The position on the profile which is adjacent to the Isle of Pines lies within the very shallow platform which represents the southeastern extension of the New Caledonia Ridge. Here, multiple reflections from the shallow sea-floor obscure the seismic record from any possible subsurface structures which may be present. This ridge marks the western limit of the morphological basin but the limit of the geological basin occurs further to the east as indicated in Figure 5.

On the eastern flank of the New Caledonia Ridge, between its crest and the geological basin, three geological features are distinguished. The first is the uppermost formation which is labelled A in Figure 5. This represents sediment in which some irregularity in reflections is present, suggesting that some slumping and minor internal faulting has occurred.

At the base of this formation there occurs a very strong, sub-horizontal reflector which is particularly marked in the eastern part of the ridge flank towards the western limit of the geological basin. The strength of the reflection implies an indurated surface at a major unconformity with the underlying layer, the reflections from which are of an irregular and strongly dipping nature. There may also be present a thin layer overlying the unconformity surface which has been eroded to form a platform. The unconformity surface and possible thin overlying layer are labelled B in Figure 5.

The formation underlying the unconformity surface, which shows marked dips and irregularities in its internal structure appears to have been subjected to some tectonic activity. It constitutes the basement of the unconformity and of the geological basin to the east, and is labelled C1 and C2 in Figure 5 because of some internal layering which appears to be present.

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To the north of profile F, the central part of the ridges emerges to form the island of New Caledonia, but only profiles C and D have extended far enough to the west to show the step that marks the western limit of the geological basin.

On profile D to the south, formation C is again observed where it extends further to the east in the form of a bulge. Here it is devoid of more recent sediment cover and formations I and II of the geological basin terminate on the eastern flank of the bulge. On profile E, however, both formation A and the possible formation B are again present, limiting the extent of the depression found on profile C.

Further to the south on profiles I and J the western margin of the morphological basin is not apparent and this basin must terminate between profiles E and I. It is possible, however, that on profiles G and H extend far enough to the west. It is of note that the southern limit of the geological basin is also placed between profiles E and I. Above profiles do not cover or define the southern extension of the flanks of New Caledonia which ends at the Isle of Pines.

From the above it emerges that the western limit of the geological Loyalty Basin, which is constituted by formation C and its unconformity surface, runs parallel in direction to that of the New Caledonia between profiles A and E. At the level of profiles C and E, it bends southwards towards the direction of the New Caledonia - Norfolk Ridge in an area coinciding with the extension of formation C further to the west.

In attempting to correlate the formations encountered above, it appears that formation III of the geological basin rests on formation C (?) as basement and that this formation probably correlates with formation D to the east. Formation A is thought to be fairly recent and we correlate this with formation I. Formation II and III of the geological basin would then be represented by the unconformity surface and possible formation B. The present position of the unconformity surface, which occurs at a depth of about 600 m, implies that a considerable subsidence of about this amount has taken place and that this has occurred subsequent to the deposition of formation III and possibly also formation II.

This would imply considerable mobility of the earth's crust in this region, which is rather to be expected. This is supported by the apparent changes in the area of sedimentation and provenance between the formations III, II and I of the Loyalty Basin. It is also suggested by the indications of faulting on the profiles, some of which may represent major normal faulting of the crust (see Figure 5).

Eastern margin of the Loyalty Basin

The eastern margin of both the morphological and geological basins is constituted by the Loyalty Ridge. This ridge parallels the island of New Caledonia in the north, and at a latitude of 22° - 23° S it also bends to the south but diverges slightly from the north-south direction of the Norfolk Ridge.

The seismic profiles provide little information on the composition (whether sedimentary or volcanic) or the structure of the ridge. Within the geological basin, the formations I, II and III gradually thin towards and terminate at the ridge. The relation between formation IV, which has been taken as basement to the geological basin, and the ridge is not well enough defined and age relationships are obscure. However, it is quite possible that formation IV is of similar age and possibly composition to that of the Loyalty Ridge. It is also difficult to say whether the ridge which may be followed from profile A to profile J, is a single structural unit with a unique age. It close proximity to the New Hebrides Trench towards the southern part of the ridge, and possible relations to the Hunter Fracture Zone complicate this picture.

MAGNETIC RESULTS

Total field magnetic profiles were obtained during the course of the seismic survey of the Loyalty features are part of a wider coverage which is reported by LAPOUILLE et al (1974). On the area of the Loyalty Basin and Ridge, however greater prominence is given here because of the entity of the area.

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Also, greater emphasis has been placed on the magnetic modelling of the Loyalty Ridge in order to test the consistency of the magnetic anomalies associated with the ridge with that of a predominantly sedimentary or volcanic composition. This is particularly in regard to the evolution of this feature and its possible relations to New Caledonia.

The magnetic anomaly profiles after the removal of the I.G.R.F. are shown in Figure 7. Included in this figure are profiles within this area obtained by the Mobil Oil Corporation from the R/V Fred H. Moore in July-1972, which provide similar and consistent anomaly profiles over the Loyalty features with those of this survey

Loyalty Basin

General observations regarding the Loyalty Basin are that it is characterised by long wavelength, negative anomalies which may be readily correlated between profiles A and E. This is consistent with the thick accumulation of sediments within the basin.

South of profile I, the anomalies cannot be correlated and it is apparent that between profiles H and I, there exists a magnetic discontinuity which is probably related to a structural discontinuity across the strike of the basin. This coincides with the position at which the southern limit of the geological (and morphological) basin was taken and enhances this conclusion drawn from the seismic survey.

Loyalty Ridge - results of magnetic modelling

A major, normal magnetic anomaly with an amplitude between about 800 and 1100 gamma strikes along the Loyalty Ridge. This anomaly and hence the ridge itself, appears to terminate to the north near latitude 18° S. To the south it becomes complex and poorly defined at about 24° S. The positive anomalies occur to the northeast of the islands and are centred on the northeastern edge of the ridge. In general, the anomaly retains basically the same form along the length

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of the Loyalty Ridge, although it is often complicated by local anomalies of comparable amplitude particularly to the west of the ridge.

The amplitude of the major anomaly varies in response to changes in the water depth and broadens as the ships tracks become less perpendicular to the strike of the ridge. These features suggest that the source of the anomaly is essentially a single uniformly magnetized body reasonably close to the sea floor.

Initial magnetic modelling along tracks normal to the ridge and near the centre of the island chain showed that the source of the magnetic anomaly could be roughly approximated by a two-dimensional, vertically sided prism centrally located beneath the ridge with a depth to the top of 1.9 km, a width of 22 km and a normal magnetization of 140 emu (figure 5). In order to take the regional of about 2 gamma per km with value increasing to the northeast was inserted. This would be consistent with a generally shallower magnetic basement to the east of the ridge.

Further two-dimensional computer modelling of centrally located tracks was then done using the polygon method of Talwani and Heirtzler (1964). The magnetic data along essentially perpendicular tracks across the ridge were filtered to reduce the influence of local anomalies and processed using computer procedures developed at the University of NSW for the treatment of marine geophysical data (Craig 1974). The computer model was used in the initial magnetic interpretation and existing seismic information on the crustal structure in the region of Shor et al. (1971) and Dubois (1971).

An example of the final interpretation of another centrally located track at the position of profile E, is shown in figure 6 together with the bathymetry. It can be seen that the measured magnetic anomaly is adequately fitted by adjusting the top surface of the model. Further refinements could be made to achieve an even closer fit but these were considered unwarranted in the present study. For this model a somewhat higher magnetization of 230 emu was used, which suggests that the source of the high amplitude anomaly over the Loyalty Ridge consists of a substantial thickness of volcanic rock which makes up the bulk of the ridge. The Loyalty Ridge therefore appears to be essentially composed of [illegible] material.

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It is therefore at least consistent with the hypothesis that the Loyalty Islands represent the ancient andesitic volcanic arc above an old Benioff zone which was associated with the inferred ancient New Caledonian Trench.

Southern extension of the New Caledonia Ridge

Profile F, which passes near the Isle of Pines, shows a large magnetic anomaly of about 900 gammas to the south of the island. Since the island contains part of the mass of peridotites which occur on New Caledonia, the anomaly may be produced the submarine extension of the peridotites or basalts. Since the anomaly is negative, this could be produced by either a reversed magnetisation or overturning of a normally polarised sheet.

SEDIMENTATION IN THE LOYALTY BASIN

Because of the thick accumulation of sediments in the Loyalty Basin, it is pertinent to look at the nature of the present and part sedimentological regimes within the basin.

On New Caledonia, a study of the actual phenomena of erosion of the peridotites and the transportation of the erosional products by Baltzer and Trescases (1971), has shown the importance of chemical erosion and transportation of dissolved material compared with mechanical transportation which occur in the ratio of 4.5 to 1. Indeed, mechanical erosion is less than the residual deposits of chemical erosion. The products of mechanical erosion which are transported mostly during the cyclonic floods, are deposited mainly in the alluvial plains and in the mouths of rivers near the coast, where mangroves act as a filter (Launay, 1972). Terrigenous deposits do no actually reach the lagoon at the present time (Launay, 1972 ; Dugas, 1974), which explains the absence of terrigenous sedimentation in the Loyalty Basin at the present time. The question obviously arises as to whether erosional processes have been constant in the part. Certainly during the Quarternary, both in the lagoon (Launay, 1972) and to a depth of 600 m on the continental slope of New Caledonia (ORSTOM, Nouméa, 1971 ; Anglada et al., in

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terrigenous deposits are not an important factor although it is possible to find episodic ferruginous, terrigenous deposits. Also, core drilling on the western barrier reef down to basement at 220 m (Avias and Coudray, 1967) shows reefal and parareefal formations (Coudray, 1971) of Quaternary age without any important terrigenous phase. Even in the marls Miocene of Nepoui, which is the only known occurrence in New Caledonia (Routhier, 1963), the terrigenous intercalations are only a few meters thick.

It therefore appears that New Caledonia has not been a source of terrigenous deposits throughout the Quaternary. Moreover, since the deposits both in the Loyalty Basin and in the New Caledonia Basin to the west, are thickest near New Caledonia (Dubois et al., in prep.) it is reasonable to suppose that New Caledonia has been an input area mainly in the past. Similarly, since volcanic activity occurred in the Loyalty Islands before 10 m.y. ago (Launay et al. sous presse) it is likely that the ridge acted as a source of volcanic and detrital material until subsidence reached nearly its present depth of 1 to 2 kms.

Dredging from the surface of formation I on some the slopes of New Caledonia obtained calcareous ooze containing pelagic well bearing micro-fauna but no terrigenous material. Other dredging in Loyalty Basin obtained mud with less globigerina and no detrital material. Present sedimentation within the Loyalty Basin is purely pelagic without terrigenous or detrital material, despite the proximity of the reefs of New Caledonia and the Loyalty Islands.

Since the total thickness of formations I, II and III do attain a two-way reflection time in excess of 4 sec, a purely pelagic sedimentation regime cannot have been in existence since the Oligocene. For comparison, drillhole 206 of Leg XXI of D.S.D.P. (Burns et al., 1972 ; Andrews et al., 1973) found the top of the Oligocene under 420 m of purely pelagic sediments. Hence it is clear that previously, considerable terrigenous material was added to the pelagic sedimentation in the Loyalty Basin. These deposits appear to have come from both the New Caledonia Ridge and the Loyalty Ridge at times during the history of sedimentation.

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CONCLUSIONS

Within the morphological basin between New Caledonia and the Loyalty Islands, seismic reflection profiles reveal a thick accumulation of sediments in a restricted basin within the broad morphological feature. This geological or sedimentary basin is limited in the east by the submarine flank of the Loyalty Ridge, and in the west by an exposed basement scarps. Between this scarps and the continental slope of New Caledonia, this basement of the geological Loyalty Basin shows a well developed platform which represents a marked unconformity with the relatively thin overlying sediment cover. Dredging from the exposed scarp has obtained samples of a well cemented ferruginous conglomerate which contains basaltic pebbles from New Caledonia.

The width of the geological basin is roughly 160 km while the total width of the morphological basin in which it occurs is about km. The northern limit of the geological Loyalty Basin remains undefined from the present survey, with thick sediment accumulation continuing northward, perhaps until the position of the d'Entrecasteaux Fracture Zone. The southern limit of this geological basin is marked where the deep sediments of the basin terminate at a latitude of S. This is south of where the axis of the basin bends southwards.

Within the geological basin, three principal formations have been identified. These have been labelled formations I, II and III. These have been laid down on a basement which was too deep to be observed in the central part of the basin, but is observed on the flanks. The basement to the west, on which the unconformity surface is located, has been labelled formation C to the east, the basement is taken as a layer which is labelled formation IV and appears to correlate with the basement with a velocity of about 5.9 km/sec found by Shor et al. (1971) from marine refraction data. This basement rises towards, and may be continuous with, the formations of the Loyalty Ridge. It is correlated with the basement C' on the western side of the basin.

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The relatively thin sediment overlying the marked unconformity to the west of the geological basin is taken to be mainly equivalent to formation I within the basin, and relatively young. The very strong reflections at or near the unconformity surface do not preclude the existence of a very thin overlying layer. This possible but uncertain layer could represent the equivalent of formation II within the basin and just possibly formation III.

However, irrespective of whether a very thin layer is present overlying the strong unconformity, it is clear that this old erosional surface must have submerged about 2 000 m to its present position, and that it must have been at or near the surface at the time of deposition of formation III and probably of formation II. This implied subsidence of the erosional platform and, indeed basin, would be due to major normal faulting or possibly folding along the eastern continental slope of New Caledonia.

It is known that a major orogenic phase, related to a readjustment between lithospheric plates, affected the region of New Caledonia and the Loyalty Islands during the Upper Eocene. Since the formations labelled I, II and III within the Loyalty Basin have not sufferred any serious deformations, it must be concluded that they were not affected by that major orogeny. It follows that they must have been deposited after this phase, that is since the beginning of the Oligocene. However, the precise age of the onset of this sedimentation is not known. The subsidence of the old erosional platform or unconformity, however, would therefore appear to be post Oligocene, possibly in the Miocène even Pliocène.

Although sedimentation in the Loyalty Basin has been restricted to pelagic sedimentation during the Quarternary, the large accumulation of sediment in the Loyalty Basin and the varying distribution of the sediment in the different layers, points to both the New Caledonia and the Loyalty Ridges as having been important sources of sediment at various times from the Oligocene. Also, the presence of three major sedimentary formations separated by disconformities implies the existance of three different morpho-tectonic and sedimentological phases in the development of the Loyalty Basin.

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Because the Loyalty Ridge as well as the New Caledonia Ridge, definately appears to have acted as an important source of sediment for formation [illegible] and particularly formation II, it is implied that it cannot be considered only as a basaltic, volcanic chain developed over a relatively short period prior to the cessation of volcanic activity 10 m.y. ago. It must have been in existence prior to the Oligocene and it most probably represents the andesitic volcanic-volcanoclastic island arc associated with an inferred Benioff zone of the ancient New Caledonia trench. The results of precise magnetic modelling of the anomalies over the Loyalty Ridge being essentially composed of material with a uniform magnetization which is appropriate to rocks of intermediate to basic composition. This is totally consistent with the above hypothesis that the Loyalty Ridge represents an ancient andesitic volcanic arc which has sufferred subsequent phases of basaltic volcanism probably related to major, tensional block faulting during its subsequent history up until 10 m.y. ago.

Finally, from the magnetic profiles across the Loyalty Ridges and the precise modelling of these profiles, it emerges that not only is the ridge composed essentially of uniformly magnetised material of intermediate to basic composition, but that there is a consistent though minor associated ridge of [illegible] magnetisation within but on the western edge of the main ridge. This gives the ridge a double aspect with the minor associated ridge on its western side providing an intra-ridge basin which has been clearly observed on seismic profiles.

ACKNOWLEDGEMENTS

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Figures Captions

1. LOCALISATION OF THE PROFILES .

   Heavy lines seismic tracks

   Dashed lines, bathymetric profile Coriolis 1966

   Hachured zone, Loyalty Basin

   Bathymetry for the Scripps map

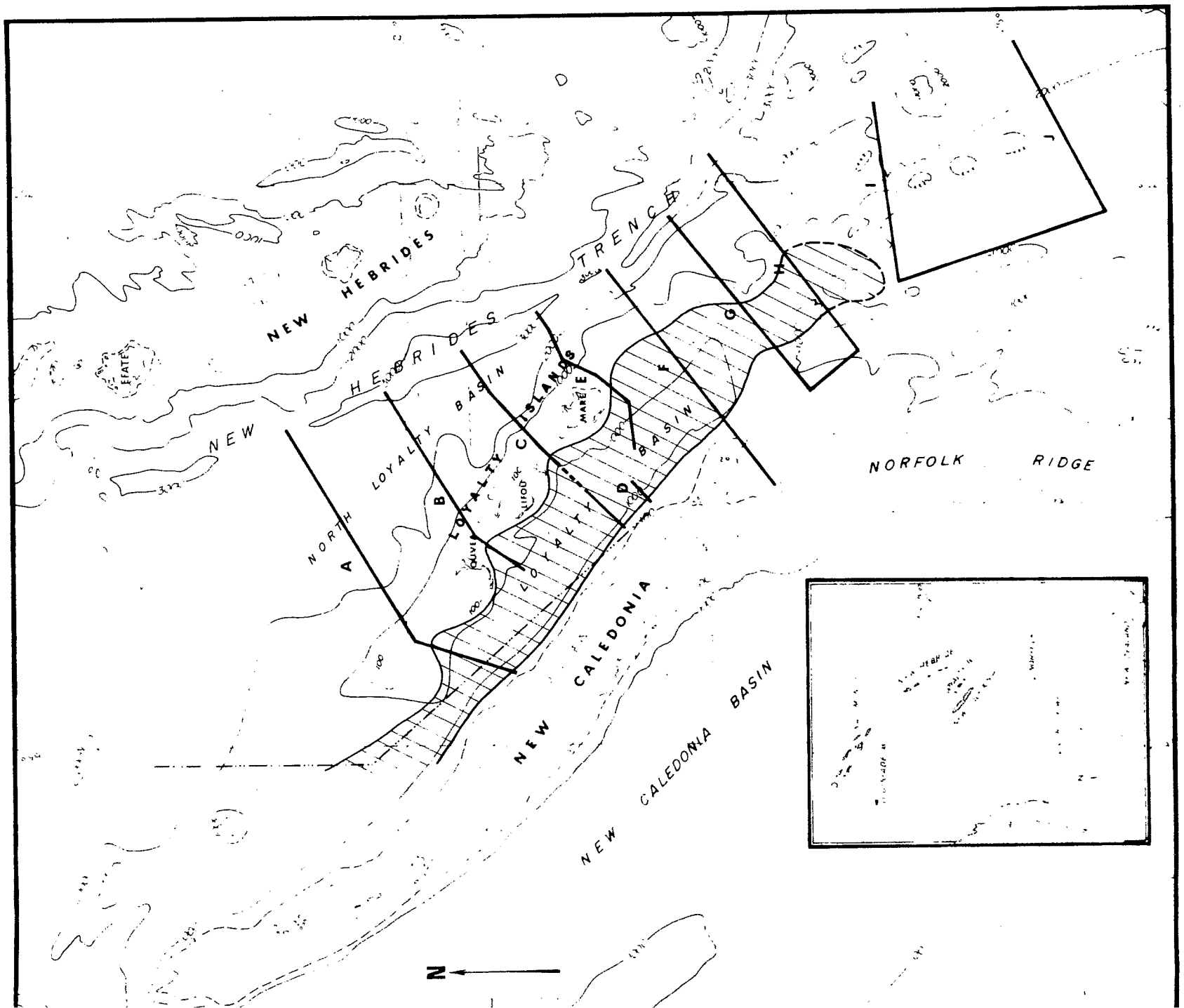
2. BATHYMETRIC PROFILES

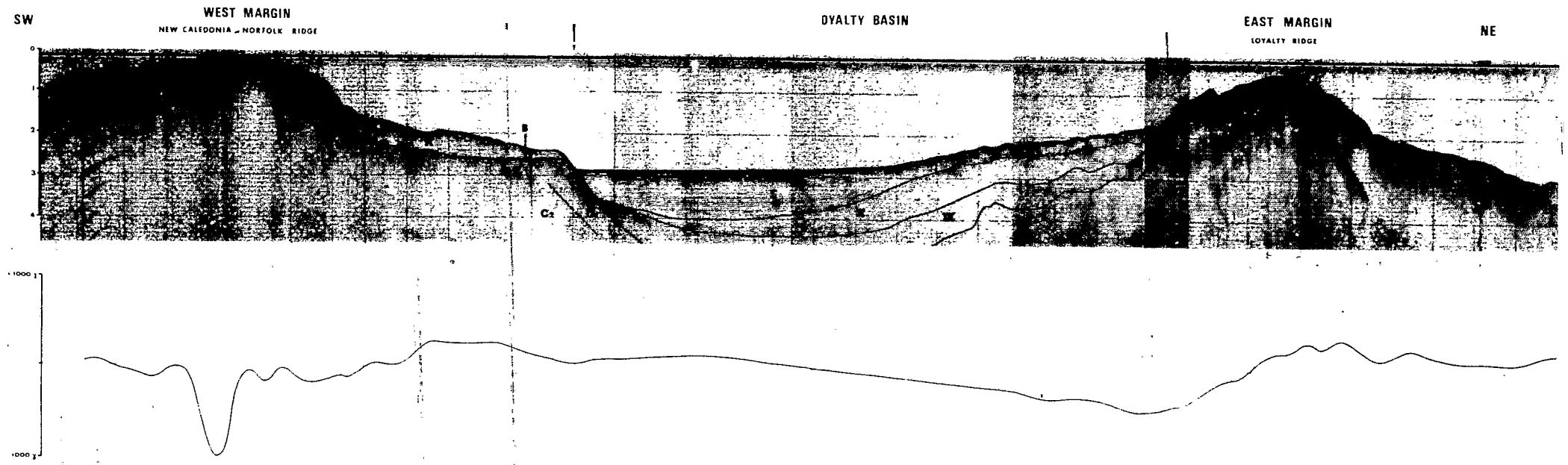
3. BATHYMETRIC PROFILE CORIOLIS 1966

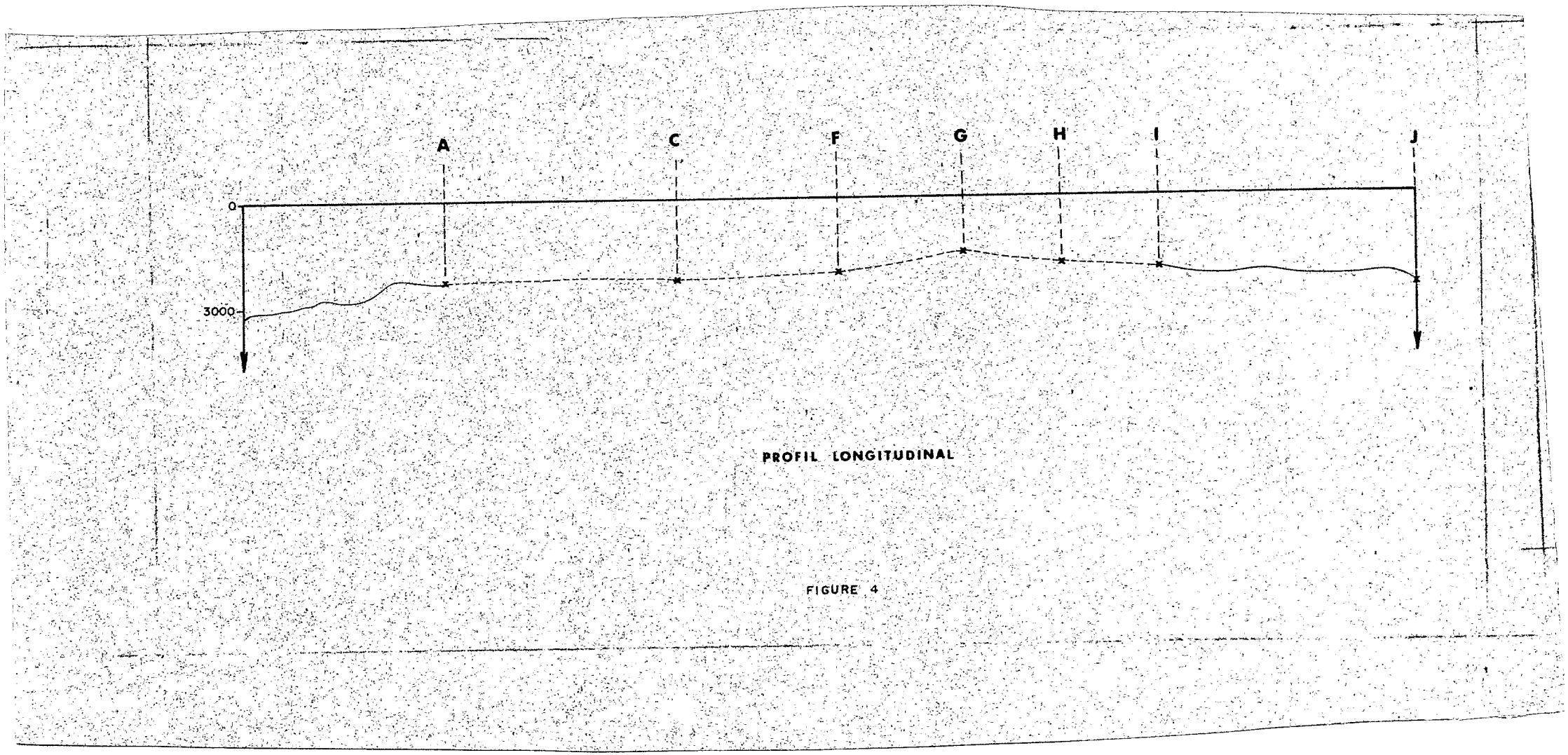
4. LONGITUDINAL PROFILE OF THE BASIN

5. F PROFILE? SEISMIC AND MAGNETISM

6. LONGITUDINAL SECTION OF THE BASIN .


NEW HEBRIDES TRENCH
NEW HEBRIDES BASIN
NEW
NORTH
LOYALTY BASIN
LOYALTY ISLANDS
MARIE
BASIN
NORFOLK RIDGE
NEW CALEDONIA
NEW CALEDONIA BASIN
N


SW
WEST MARGIN
NEW CALEDONIA – NORFOLK RIDGE
DYALTY BASIN
EAST MARGIN
LOYALTY RIDGE
NE
0
1
2
3
4
C2
+1000
-1000



PROFIL LONGITUDINAL

FIGURE 4

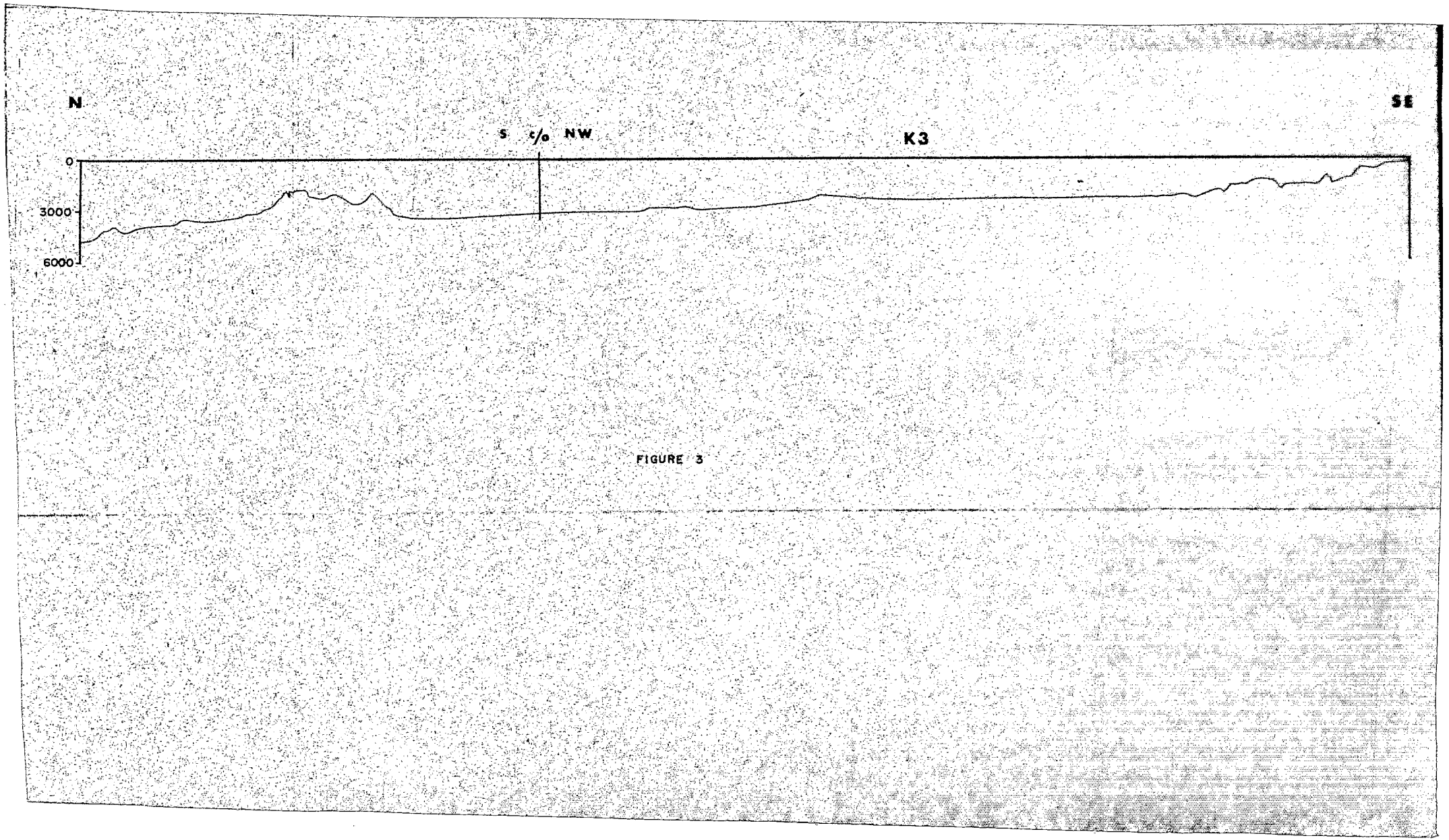
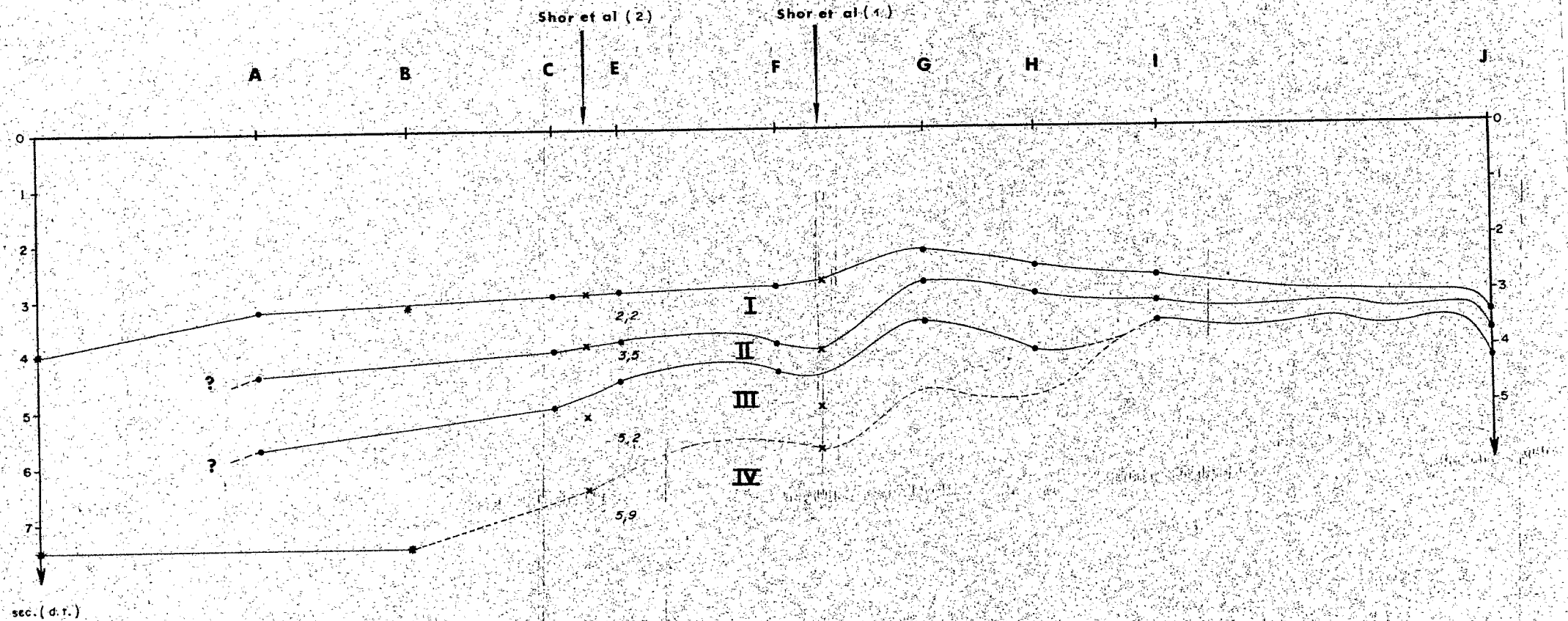


FIGURE 3

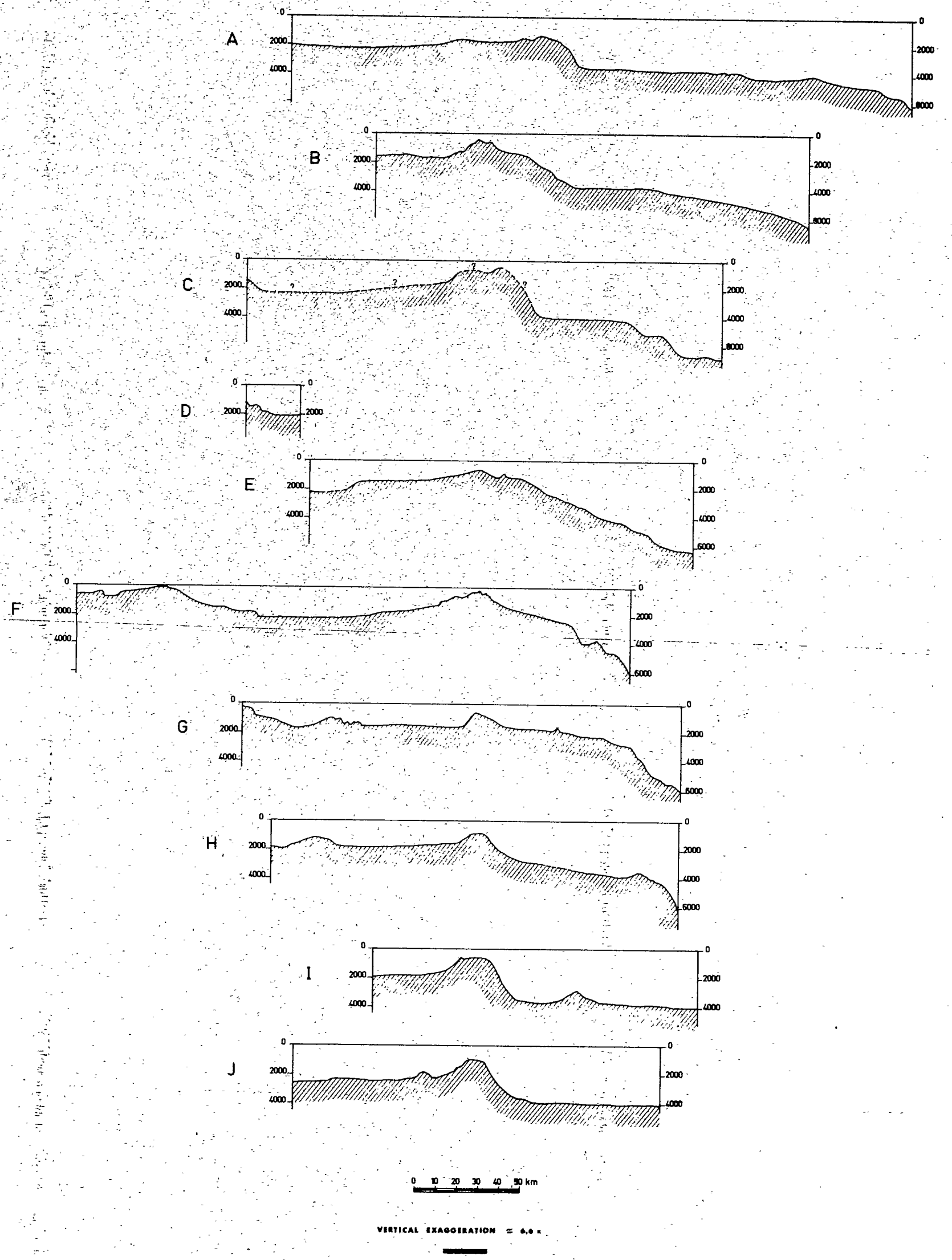


LÉGENDE

- Profils Kimbia-Coriolis
- × Données Shor et al
- ✱ Données Dubois et al

FIGURE 6

SW NE


A
B
C
D
E
F
G
H
I
J
0
2000
4000
6000
8000
?
0 10 20 30 40 50 km
VERTICAL EXAGGERATION ≃ 6,6 x