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Continental Shelf Definition in the Lord Howe Rise and Norfolk Ridge Regions: Law of the Sea Survey 177, Part 1 - Preliminary Results

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CONTINENTAL SHELF DEFINITION IN THE LORD HOWE RISE AND NORFOLK RIDGE REGIONS : LAW OF THE SEA SURVEY 177, PART 1 - PRELIMINARY RESULTS

by

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EXECUTIVE SUMMARY

This report covers the preliminary results from the first of two cruises designed to test the area around Lord Howe Rise and Norfolk Ridge for Australia's claim to 'legal' Continental Shelf (LCS) beyond the 200 n mile EEZs around Lord Howe and Norfolk Islands. Following a desk-top study conducted jointly with New Zealand scientists in May 1996, these two cruises incorporate separate lines by means of which New Zealand will test for LCS beyond its EEZ in the same general area, under a contract between the NZ Ministry of Commerce and AGSO. Furthermore, the contract specifies the sharing of all data collected on both surveys.

This cruise commenced at Brisbane on Friday 13 September and ended at New Plymouth, New Zealand on Thursday 24 October 1996. During the cruise, deep-penetration seismic data along three lines totalling 2321 km for Australia and six lines totalling 1839 km for New Zealand were recorded, principally in the region of the Norfolk Ridge, the Norfolk Basin and the Three Kings Ridge to the edge of the South Fiji Basin. In addition, bathymetric and gravity data were acquired on all lines and transits between lines and ports; magnetic data were acquired on most lines and transits. 24 sonobuoys were deployed to try to determine the sonic velocities for the sedimentary layer(s) and for the (generally basaltic) basement rocks beneath. Precise navigation was provided by two differential GPS systems. All the aims of the survey were satisfactorily met.

Examination of the on-board monitors has given preliminary positions for both potential foot-of-slope (FoS) picks and the 2500 m isobath, necessary parameters in making a claim to LCS. This survey has confirmed the extremely complex nature of this area. The basement is certainly not 'normal' oceanic crust and picking a position of FoS according to the formulae provided in Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS) is somewhat problematic. Nowhere was the apparent sediment thickness sufficient to warrant an extension of the edge of the claimable LCS beyond 60 n mile from the FoS. Accurate positions for possible picks and accurate estimates of sediment thickness will have to await final processing of all the survey data.

INTRODUCTION

The general geological framework and technical planning for this survey are documented in reports on a joint desk-top study undertaken in May 1996, on behalf of the New Zealand Ministry of Commerce and the Australian Geological Survey Organisation (AGSO). In those reports (*NIWA-IGNS,* 1996; Lockwood et al., 1996), existing data relevant to Australia's and New Zealand's potential 'legal' Continental Shelf claims under the 1982 United Nations Convention on the Law of the Sea, Article 76 (UNCLOS, 1983; 1993), in the general region of Lord Howe Rise and Norfolk Ridge, were compiled and interpreted. Deficiencies in the existing historical databases were evaluated, and additional data requirements necessary to support Australia's and New Zealand's claims beyond their present Exclusive Economic Zones (EEZs) in those regions were quantified.

Australia and New Zealand have very large potential LCS claims to adjacent parts of the Lord Howe Rise, the New Caledonia Basin and the Norfolk Ridge system on the basis of natural submarine prolongation from New Zealand, and from Lord Howe and Norfolk islands, which are situated on the Lord Howe Rise and Norfolk Ridge, respectively (Fig. 1). New Zealand also has a potential claim to the Three Kings Ridge and southwestern South Fiji Basin (SFB), which may also be subject to a claim by Australia and possibly France (New Caledonia), if these countries can demonstrate natural prolongation eastwards from the Norfolk Ridge into the northern Three Kings Ridge area. Areas of common claim will have to be settled by government to government negotiation.

The desk-top study showed that deep-penetration, high quality seismic reflection profiles, together with extensive, well positioned bathymetry data are required to support both Australia's and New Zealand's claims. Logistic constraints imposed by the vast size of the above regions require the acquisition of new data to be undertaken on several surveys. AGSO and the New Zealand Ministry of Commerce decided to take advantage of cost efficiencies and technical collaboration by undertaking joint surveys in these regions in late 1996. The surveys involved the acquisition of high-fold, deep-penetration (16 sec two-way-travel time, TWT) seismic reflection profiles using R/V *Rig Seismic* on two consecutive cruises: the present survey to the Norfolk Basin/Three Kings Ridge area, and the other to the Challenger Plateau/Lord Howe Rise area. New Zealand also expects to conduct a second phase of surveying in the region involving acquisition of bathymetry and complementary, shallow-penetration (2-5 sec TWT) seismic reflection data. This second phase will be planned in 1997 with consideration to both existing data and the seismic profiles obtained on the present survey. Australia will probably also need additional information to support its potential claim in the Three Kings Ridge region; however, any additional requirements must await a detailed examination of the results of this *Rig Seismic* survey.

This survey, and the following survey of the Challenger Plateau/Lord Howe Rise area, were undertaken under a fully collaborative agreement between the New Zealand Government and AGSO. The New Zealand data were acquired by AGSO under the terms of a contract between the New Zealand Ministry of Commerce and AGSO. The New Zealand representatives onboard *Rig Seismic* for the data acquisition were provided by the National

Institute of Water & Atmospheric Research Limited (NIWA) and the Institute of Geological & Nuclear Sciences Limited (IGNS), the same institutions represented in the earlier desk-top planning phase. All the survey data collected will be openly shared by Australia and New Zealand, both for the purpose of UNCLOS requirements and for any scientific initiatives that may evolve from the two surveys.

On this cruise (Survey 177, Part 1), a total of nine lines were proposed. Six lines (NZ-D to NZ-I) totalling 1862 km were commissioned by New Zealand to help establish the extent of natural prolongation from the Three Kings Ridge, to further define the foot-of-slope (FoS), to provide information on sediment thicknesses beyond the FoS, and to help constrain both the continuous and isolated closures of the 2500 m isobath. Three lines (LHRNR-B to LHRNR-D) totalling 2355 km were planned by AGSO as reconnaissance profiles to test for evidence of natural prolongation eastwards from the Norfolk Ridge onto the Three Kings Ridge, and to provide modern FoS data to support a claim over the New Caledonia Basin south of the negotiated boundary with France. Twenty four sonobuoys were deployed to measure sonic velocities for the sedimentary layers, in order to help constrain sediment thickness estimates (Appendix 3). Figure 1 presents the locations of the lines actually acquired on the survey.

This report presents a preliminary interpretation of the shipboard survey results, within the context of UNCLOS Article 76 (UNCLOS, 1993). To illustrate the types of data acquired, Figure 2 presents an onboard processed brute stack of part of seismic profile NZ-I, with various UNCLOS parameters identified. Figure 3 illustrates one example of the 15 successful sonobuoy refraction profiles obtained. In all sonobuoy profiles the sediment/basement contact appears as a strong refractor. Shipboard monitor plots of gravity, magnetic, and echosounder data were recorded routinely on all lines (Fig. 4). Figures 5 to 10 include shipboard interpretations of single-channel monitor plots of each of the seismic profiles. The specific locations of UNCLOS features, such as FoSs, reported here are preliminary only and are subject to modification following final data processing and interpretation. In this report, we present for each line the objective of the profile, a description of the major features, and a brief discussion of the preliminary data in terms of LCS delimitation.

ACKNOWLEDGMENTS

The enthusiasm, skill and cooperation of the master and crew of the *Rig Seismic* are gratefully acknowledged. They made a major contribution to the successful completion of all the objectives of the cruise. In particular, the streamer cable break which occurred on line NZ-H was handled in an extremely professional manner, thereby causing minimal disruption to the program. A list of all the crew for this survey appears at Appendix 4.

LINE ACQUISITION

Lines with LHRNR prefix are AGSO lines; NZ prefix refers to New Zealand lines.

Survey Lines	Planned	Actual
LHRNR-B	1139 km	1201.7 km
LHRNR-C	835 km	778.7 km
LHRNR-D	381 km	340.7 km
NZ-D	243 km	243.7 km
NZ-E	311 km	239.0 km
NZ-F	267 km	289.2 km
NZ-G	324 km	314.8 km
NZ-H	271 km	311.5 km
NZ-I	446 km	440.5 km
Australian total	2355 km	2321.00 km
NZ total	1862 km	1838.55 km
Cruise Total	4217 km	4159.55 km

LINE DESCRIPTIONS AND ONBOARD INTERPRETATION

It should be emphasised that the following line descriptions, and the interpretations of UNCLOS parameters such as FoSs and locations of the 2500 m isobath, are preliminary only and should not be considered as binding on either Australia or New Zealand. They are not necessarily indicative or representative of the arguments that either the Australian or New Zealand governments might put forward in support of their final claims for LCS in the survey area.

The main survey area to the east of Norfolk Island does not conform to the idealised continental margin to which UNCLOS Article 76 (Appendix 1) readily relates. Therefore, on most lines, several possible positions for the FoS have been nominated. Many of these FoS positions lie within the complex ridge systems between the Norfolk and Three Kings Ridges, and do not appear to fit the definition of FoS as contained in Article 76, i.e. "maximum change in gradient at its base". This definition would imply that the FoS positions relevant to Article 76 are those lying to the east of the Three Kings Ridge on the edge of the SFB. The final FoS positions used to define the outer limits of Australia's and New Zealand's LCSs in this region will clearly depend on the prevailing interpretation of Article 76 at the time of claim submission.

In the following discussion, a variety of informal terms are used that relate to application of Article 76 of UNCLOS, eg. the Hedberg Line. These terms are defined in Appendix 2.

LHRNR-B

Objective: Profile LHRNR-B was planned to extend for 1139 km from the Lord Howe Rise, across the New Caledonia Basin and Norfolk Ridge, across the northern edge of the Norfolk Basin, and onto the northern end of the Three Kings Ridge (TKR; Fig. 1). The overall trend of the line is E-W, and it lies between 26° and 28°S. A primary objective of the line, in terms of UNCLOS Article 76, was to test for eastwards natural prolongation from the Norfolk Ridge into the TKR area. The line was also designed to reveal positions of the FoS on both sides of the New Caledonia Basin, and thus support Australia's claim across this feature. Should the data successfully confirm prolongation onto the TKR, the lines commissioned by New Zealand should help to constrain the extent of the prolongation into the SFB.

Line Description: From west to east this line commences at about the middle of the Lord Howe Rise at shot point (SP) 27030, in about 1390 m water depth (Fig. 5). The crest of the rise is smooth and convex, reaching a minimum water depth of 1125 m. The crest between SP 25200 and SP 24150 is underlain by 350 - 400 ms two-way-travel time (TWT) of sediment resting on a planated basement platform. Extensional fault-bounded basins occur beneath both flanks of the basement platform. Beneath the upper, western flank, a 48 km-wide basin contains at least 2 s of sediment, and beneath the eastern flank, two faulted basins contain up to 1.4 s of sediment. The lower 1.0 - 1.2 s of the basin fill is probably Cretaceous in age. The eastern lower flank of the rise and the 3640 m-deep floor of the New Caledonia Basin are underlain by up to 1.6 s of sediment, the lower 0.4 - 0.8 s of which occurs in normal-faulted basins about 15 - 30 km wide. At the foot of the lower slope of the Lord Howe Rise, a basement high is exposed between SP 18750 and 18620.

The eastern flank of the New Caledonia Basin climbs from the basin floor onto the crest of the Norfolk Ridge, which at SP 15400 is about 670 m deep (Fig. 5). This slope is highly irregular, probably due to erosion, and the lower part is underlain by at least 1 s of sediment. Continuing from the crest of the Norfolk Ridge the profile trends approximately east-west for 187 km, to a course change at SP 11650/10650 (at the break between Figs. 5 and 6). The eastern slope of the ridge is underlain by sediment about 200 - 500 ms thick, and descends steadily for 85 km from the ridge crest to SP 13700. At this location the sediment thickens into a 2740 m-deep, 16 km-wide basin containing up to 1.5 s of sediment (SP 13510). A large, sediment free, double-peaked basement complex lies beyond, between SP 13370 and 12580, with peaks rising to minimum water depths of 1800 m at SP 13300, and 1140 m at SP 12720 (Fig. 5). Between SP 12580 and the course change at SP 11650/10650, two sedimentary basins are separated by a basement ridge about 2500 m deep. The basins contain 600 - 900 ms of sediment, and occur at water depths of 3165 m and 3050 m respectively.

Over the following 370 km of line southeast of the course change, the line firstly trends N150° to intersect the ridge system traversing the central Norfolk Basin (tested by line LHRNR-C), and then swings more easterly (N110°) towards the northern end of the TKR (Fig. 1). This entire section of the profile between SP 11650/10650 and SP 3200 crosses a series of three prominent bathymetric ridges or seamount complexes, that are flanked and separated by four basins, three of which contain sediment 0.6 - 0.8 s thick (Fig. 6). These major features are consistent with the most recent bathymetric interpretation of the region, and with satellite gravity data. The ridges or seamounts have peaks at about 2060 - 2200 m water depth (SP 9550, 8950, 7790, 5890, and 5590; Fig. 6). The intervening basins occur approximately between SP 10650 and 10100, SP 8000 and 8230, SP 7150 and 6800, and SP 3970 and 3200. They attain water depths of about 3150 m, 3900 m, 3750 m and 3800 m, respectively. The last basin, nearest the TKR, appears to be fault bounded. At its western edge is a normal fault that downthrows the basin floor to the east. The eastern flank of the basin (about SP 3200) is a steep, linear escarpment of exposed basement rock representing the western edge of the TKR. No fault is identified in the shipboard monitor seismic plots, but the linear form of the basement ridge on bathymetry and gravity maps indicates a possible tectonic control at a crustal level. The top of the basement ridge at SP 3050 is close to 2500 m deep, and coincides with a strong positive gravity anomaly.

Between the ridge and the main crest of the TKR at SP 1350 is a 70 km-wide perched basin containing at least 1 s of sediment (Fig. 6). Profile LHRNR-B intersects with lines NZ-D and NZ-E on the sediment-free crest of the TKR. Almost 1 s of sediment occurs on the upper flank of the TKR at the eastern end of the profile (SP 1001).

Brief comments on UNCLOS parameters: Locations of 2500 m isobath occur on each side of the New Caledonia basin: on the western flank of the Norfolk Ridge at SP 16150, and on the eastern flank of the Lord Howe Rise at SP 22580 (Fig. 5). Similarly, possible FoS positions occur at SP 16782 west of the Norfolk Ridge, and at SP 18630 east of the Lord Howe Rise. In the area of very complex bathymetry east of the Norfolk Ridge there is a potential morphological FoS position in the North Norfolk Basin at SP 8230, where the inner edge of the deepest (3900 m) depression occurs. East of this position, depressions occur at a shallower or similar water depth and may define other potential FoS locations. The position of the 2500 m isobath on the eastern flank of the Norfolk Ridge occurs at SP 13810. East of this, there are more than 10 other positions of 2500 m occurring on the flanks of basement ridges or seamounts, west of the TKR.

On the western flank of the TKR, there is a 2500 m crossing at SP 1720, and potential morphological FoS positions with respect to the TKR at SP 3240 and 3350 (Fig. 6).

LHRNR-C

Objective: Profile LHRNR-C was planned to extend for 817 km from the Norfolk Ridge just south of Norfolk Island, across a subdued NE-SW trending ridge system composed of bathymetric highs that separates the North Norfolk Basin from the South Norfolk Basin, across the Cook Fracture Zone (CFZ), and across a complex region of ridges and seamounts north of the TKR (Fig. 1). The objective was to test whether the complex saddle area separating the North and South Norfolk Basins is a natural prolongation of the Norfolk Ridge, and whether the CFZ forms a barrier to the prolongation in the northeast. The line was scheduled to terminate close to the EEZ defined from Matthew and Hunter Islands.

Line Description: The line commences at SP 1001 in 2600 m water depth. The western 64 km of the profile climbs the western flank of the Norfolk Ridge onto the continental shelf south of Norfolk Island (Fig. 7). The lower part of the slope is relatively smooth, and is underlain by at least 2 s TWT sediment thickness. Beneath the crest of the Norfolk Ridge, which is about 35 km wide, no sub-bottom events can be observed on shipboard monitor profiles due to multiple energy. East of the Norfolk Ridge, from SP 2950 (about 300 m water depth), the slope descends over a 50 km distance to SP 3950 (water depth 2200 m), which lies on the ridge system in the Norfolk Basin. Locally, acoustic basement is exposed on this slope, but elsewhere the sediment is up to 550 ms thick.

For the next 350 km between SP 3950 and 10950, the ridge system trends firstly ENE and then NNE (Fig. 1), maintaining a water depth that typically varies between 2200 - 2500 m, until about 100 km southeast of the intersection of the profile with the CFZ (Fig. 7). The shallowest depth seen on the profile on this segment of the ridge is 1700 m (SP 6050), and the deepest is 2940 m (SP 7150). The acoustic basement is an irregular surface and is exposed in highs ranging in width from a few kilometres to 25 km. These highs are separated by depressions containing up to 800 ms sediment, although the sedimentary cover on the ridge is more typically 200 - 500 ms, predominantly weakly reflective, and probably pelagic. Between SP 10950 and 13000 (about 50 km), the ridge descends to a greater depth of about 3650 m, where the basement is covered by up to 300 ms sediment. A depth of about 3400-3700 m is maintained over the following 36 km of the profile. From SP 13750 the slope descends to about 4050 m water depth in the area of the CFZ, the axis (SP 14340) of which is devoid of sediment.

North of the CFZ the profile crosses two major seamounts, the first of which has a crest about 2650 m deep at SP 15160, and the second a crest less than 2500 m deep at SP 17740 (Fig. 7). The second seamount represents part of the ridge system imaged at the northern end of Line NZ-D. Between the two seamounts the seabed is smooth, about 4050 m deep, and is underlain by at least 300 ms of sediment. East of the second seamount the water depth increases to about 4500 m, which is the maximum recorded on the profile.

Brief comments on UNCLOS parameters: On the western flank of the Norfolk Ridge, the 2500 m depth occurs at SP 1200 (Fig. 7). On the ridge complex separating the North and South Norfolk Basins, there are 14 positions of 2500 m depth crossed by this profile, all of which occur within the Australian EEZ defined from Norfolk Island. Two additional positions at SP 17670 and 17780 occur on flanks of a seamount to the north-northwest of the TKR complex. The latter concur with data used in pre-cruise planning interpretations.
Four possible FoS positions are identified on this line. The first occurs on the ridge complex between the North and South Norfolk Basins at SP 3950, where water depths flatten off to an average of about 2200 m. A second potential FoS is identified in the axis of the CFZ (SP

14340, water depth 4050 m), a third on the eastern flank of a seamount/ridge at SP 16400 (4100 m), and the fourth at the outer edge of the profile at SP 18120 (4500 m), on the edge of the SFB. If the outermost FoS is accepted, this might provide Australia with natural prolongation into the SFB to the north of the TKR. Further surveying may be required in this area of complex bathymetry to the northeast of the CFZ to fully understand the various FoS configurations. The line was terminated about 60 km short of the survey plan, when equipment failed and it was felt that the outermost FoS position had been identified.

LHRNR-D

Objective: Profile LHRNR-D was planned to extend for 381 km from the ridge complex separating the North and South Norfolk Basins, where the profile is tied to LHRNR-C, southeastward onto the TKR (Fig. 1). The eastern end of the line connects directly into New Zealand line NZ-H. The objective was to test a possible path of potential natural prolongation from the Norfolk Ridge to the TKR.

Line description: At its western end at SP 15050, the line intersects with LHRNR-C on the irregular crest of the subdued ridge system traversing the centre of the Norfolk Basin. The profile maintains a depth of about 2500 m for 30 km, to where the slope descends into a 7 km-wide, 3150 m-deep basin containing up to 0.8 s sediment (SP 14225 - 14370; Fig. 8). For 30 km east of this basin a slope underlain by 500-800 ms of sediment deepens from 2700 m water depth at SP 14000, into a flat-floored depression between SP 13370 - 13480. The surface of the slope is characterised by regular undulations with wavelengths of 1 - 2 km and amplitudes of about 10 - 30 m. These features may be sediment waves, and evidence for strong bottom circulation in the region. The flat-floored depression is underlain by 400 ms sediment, and at 3300 m water depth, is the deepest part of the profile.

From this depression the slope climbs to the western edge (SP 13200) of an 87 km-wide terrace, that was predicted on existing bathymetry charts. The terrace slopes gently westward, decreasing in water depth from 2700 m at SP 13150 to 2250 m at SP 11500 (Fig. 8). The terrace is underlain by up to 700 ms of sediment, which covers an irregular basement reflector, and a second field of possible sediment waves occurs on the surface. At the eastern end of the terrace is a basement ridge that is 1575 m deep at SP 11320. Continuing east, the profile crosses a sediment-free depression reaching a depth of 3000 m at SP 11050, and then a perched basin between SP 10500 and 10900, comprising a lenticular sedimentary unit up to 550 ms thick, which in profile appears to be a sediment drift.

Flanking the lenticular sediment unit, a basement ridge reaches a minimum water depth of 1690 m at SP 10170. On vertically exaggerated plots, the ridge has the geometry of a normal faulted block, but the sediments in a major basin to the east do not thicken towards the steep eastern flank of the ridge. The major basin east of the ridge coincides with a strong negative anomaly on satellite gravity data, is 1870 - 2700 m deep, and contains at least 1.7 s sediment. The basement beneath the basin cannot be identified on shipboard monitor plots, so the sediment could be thicker. The crest of the TKR is about 35 km wide, comprises two peaks of exposed basement, separated by a 15 km-wide basin containing up to 900 ms of sediment.

The exposed basement highs have peaks at 1275 m (SP 8350) and 1090 m (SP 8740 and 8850) water depth respectively. The profile was completed at the eastern edge of the TKR crest at SP 8270, where it continues directly onto line NZ-H. (Fig. 8).

Brief comments on UNCLOS parameters: More than half of this profile lies inside the Australian EEZ (Fig. 1), which occurs at about SP 11189. Much of the seabed profile, between the ridge complex and the crest of the TKR, lies between 2500 m and 3000 m water depth, and is therefore elevated relative to the SFB which lies at a depth of more than 4000 m east and north of the TKR. There appear to be no obvious FoS positions on the profile, and it could be argued by Australia that natural prolongation extends from the Norfolk Ridge system onto the TKR. From Australia's perspective, one possible FoS lies at SP 13470, at the western edge of the deepest depression (3300 m) on the profile (Fig. 8). From New Zealand's perspective, a potential FoS on the western flank of the TKR occurs at the eastern edge of the same depression, at SP 13370. However, both of these positions lie well inside the Australian EEZ. When the complete survey line comprising LHRNR-D and NZ-H is considered, the most plausible, 'basal' Article 76 FoS positions occur to the east of the TKR, on the edge of the SFB (see NZ-H, UNCLOS parameters section).

NZ-D

Objective: Profile NZ-D was planned to extend for 243 km from the edge of the Matthew and Hunter Islands EEZ, onto the northern end of the TKR (Fig. 1). The objective of this profile was to test for prolongation and crustal continuity from the northern end of the TKR, across the eastern part of the NW-trending CFZ, and along a narrow sinuous ridge extending into the southwestern part of the SFB. It was anticipated that an optimally positioned profile down the axis of the narrow ridge would provide a convincing position of the FoS at the very northern end of the ridge, about 100 km north of the CFZ, as well as confirming local water depths of less than 2500 m on the northernmost high on the ridge crest. From existing data, a conservative FoS had been identified at the CFZ, together with a potential FoS at the northern end of the ridge. Existing bathymetry and satellite gravity data indicate that the ridge comprises a series of isolated highs and subdued saddles between 2500 m and 3500 m deep. The overall orientation of the line is NNW-SSE, but the trace is sinuous and varies from about 20° to 300°.

Line description: The southern 60 km of the line between SP 5900 and 4700 descends from the crest of the TKR at about 1500 m water depth to 2250 m (Fig. 9). Exposed basement rock characterises the southern 26 km (SP 5900 - 5370), where three bathymetric highs are present. A sediment basin lying between SP 5370 and 4730 contains up to about 1 s of sediment, the upper 300 - 400 ms of which is weakly reflective and may be pelagic sediment, and the lower 600 - 700 ms of which comprises strong, discontinuous reflections, possibly resulting from volcaniclastic debris or lava flows. Northward, the slope continues to descend from an exposed basement high at SP 4700, across a perched sedimentary basin containing up to 400 ms of sediment, and into the axis of the CFZ (SP 4220), which is about 4170 m deep and is devoid of sediment.

For 63 km between the CFZ and SP 2950, the line trends along the axis of the narrow ridge, typically between 3375 m and 3975 m deep (Fig. 9). The ridge is covered with up to 400 ms of weakly reflective, probably pelagic, sediment that drapes over irregularities in the basement. For the next 87 km between SP 2950 and 1200 the ridge crest is devoid of sediment and has considerable relief. Four separate bathymetric highs are present, two of which are close to 2500 m deep, and two of which are about 2900 m deep. Two of the highs are separated by a deep (4275 m) depression, that appears to segment the ridge. At the northern end of the line (SP 1001), in 4000 m of water, the basement rock is covered by 250 ms of sediment.

Brief comments on UNCLOS parameters: The 2500 m isobath occurs at SP 4625 (Fig. 9). There is an inner FoS position in the axis of the CFZ (SP 4220), and a second possible FoS at the northern end of the line north of the sediment-free highs at SP 1200. These identifications are consistent with pre-survey interpretations. From the new data, it remains inconclusive as to whether the narrow ridge complex north of the CFZ may be claimed as a natural component of the TKR, and as to whether the crust to the north and south of the CFZ are of the same composition and age. The processed magnetic anomaly data should help in this regard. Overall, there is a similarity of relief and sediment cover between the TKR and the area immediately north of the CFZ (SP 3000-4220). Together, they appear to define a gently northward sloping complex seafloor which ends at the SP 1200 FoS. Whether the thickness and location of sediment on the ridge is a function of the hydrodynamics (pelagic drape, sediment remobilisation, bottom current activity, etc.) or an indication of the relative age of different parts of the crust is uncertain, but may be pertinent to the final claim. It appears that bottom currents have hindered sedimentation in the axis of the CFZ. The northern end of the ridge has a different aspect (high relief peaks and no sediment cover). Sediment thickness in the context of an UNCLOS 1% claim is not a relevant parameter on this profile.

NZ-E

Objective: Profile NZ-E was planned to extend for 311 km from the northern end of the TKR, northeastward onto the SFB floor (Fig. 1). The objective was to test for natural prolongation from the main axis of the TKR, across a broad elevated seamount, and down the axis of a low relief, deep water (> 4000 m), NE-trending ridge. Although existing bathymetry maps show the seamount at 173°30'E; 27°S to be > 3000 m deep, satellite gravity data indicate that the crest of the seamount may be < 2500 m deep, and may thus represent an external isolated closure of 2500 m from which a favourable 2500 m + 100 n mile cut-off (informally referred to as the 'isobath cut-off line'; Appendix 2) may be defined up to 260 km from the continuous 2500 m contour on the TKR. The profile would also provide further bathymetric constraints on a second, known, small isolated closure of 2500 m between the seamount and the main body of the TKR. It was anticipated that the deep penetration seismic data will provide convincing evidence that the seamount and the subdued deep water ridge are naturally part of the TKR complex, and thus confirm a distant FoS on this line between 174° and 175°E. Sediment thickness was not anticipated to be more than a few hundred milliseconds at the outer part of the line.

Line description: The western 25 km of the line descends from about 1500 m water depth on the crest of the TKR, across a gently sloping, sediment-covered terrace to the edge of a basement exposure at SP 1550, in 2100 m water depth (Fig. 9). The sediment cover on the terrace reaches 750 ms thick. East of SP 1550 the slope continues to descend, steeply at first and then more gently, to 3900 m depth at the edge of a basement high at SP 3700. The exposed basement high between SP 3700 and 3850 attains a minimum depth of 3450 m. The eastern side of the high drops into a basin containing up to 500 ms sediment, between SP 3960 and 4270. The large seamount, suspected from the gravity data, lies between SP 4270 and 5550, is 64 km wide and attains a minimum water depth of 1050 m on this profile. From the outer edge of the seamount complex to a small high of exposed basement protruding up to 300 m above the surrounding seabed between SP 5900 and 6250, the seabed is almost horizontal and is underlain by a thin sedimentary basin 100 - 300 ms thick (Fig. 9). From the outer basement exposure to the end of line at SP 6783, the seabed slopes very gently and is covered with a veneer of sediment about 100 ms thick.

Brief comments on UNCLOS parameters: The innermost FoS position occurs at SP 3960, lying at 4125 m water depth, between the crest of the TKR and the inner edge of the large seamount complex (Fig. 9). This location coincides with the trend of FoS positions identified along the CFZ to the west. The large seamount provides two new positions of 2500 m water depth, which must lie on an isolated closure of the 2500 m isobath. The outer (northwestern) 2500 m position extends the location of the potential isobath cut-off mapped from existing data by up to 55 km, but it is considered unlikely that the cut-off will define the claim in the final shelf delimitation. A potential FoS position lies at the outer edge of the seamount complex at SP 5550. This coincides with a NNW-SSE-trending line of FoS positions identified from previous data. A third potential position of FoS lies at the end of the profile at about 4560 m water depth. An onboard decision was made to terminate the profile at SP 6783, about 70 km short of the pre-planned location. It was felt that the most realistic potential FoS had been identified at SP 5550 (Fig. 9). The combined seismic and satellite gravity data indicate that there is no chance of a sediment thickness claim beyond the Hedberg Line at the outer end of the profile. If it is considered to be worthy of the expenditure, a more distant potential FoS on the projection of this line could be investigated more cost effectively during the proposed bathymetric survey of the second phase of New Zealand's UNCLOS study.

NZ-F

Objective: Profile NZ-F was planned to extend approximately eastward from the northern end of the TKR, tying with NZ-E near an isolated closure of the 2500 m isobath, and then extending for 267 km into the SFB (Fig. 1). The line follows a broadly elevated region between 3250 m and 4000 m deep, before dropping off a small escarpment at about 175°30'E into the 4500 m-deep basin floor. The objective of the line was to demonstrate natural prolongation on the basis of both morphology and crustal reflectivity, and define a FoS as far eastward into the SFB as possible. The line was also designed to test an important isolated closure of the 2500 m isobath at 27°35'S 174°15'E, which may be used to define a distant isobath cut-off. Sediment at the end of the line was expected to be less than 1 km thick.

Line Description: The seabed along this profile is highly irregular and can be divided into three levels lying at progressively deeper average water depths towards the SFB. The inner (western) end of the line at SP 6780 commences at 2810 m water depth at the intersection with profile NZ-E (Fig. 9). In the first 10 km, the slope descends onto the upper level which is a terrace about 77 km wide (between SP 5000 and 6550) underlain by sediment typically 200 - 500 ms thick. The average water depth of this terrace is about 3300-3600 m. A bathymetric high of exposed acoustic basement in the middle of the terrace reaches a minimum water depth of 2925 m at SP 5740. The outer edge of the terrace is marked by a broad basement peak 2590 m deep and 32 km wide (SP 4260 - 4900).

The second level is a terrace 93 km wide (SP 2400 - 4260), consisting of four sediment-free peaks separated by lows with different degrees of ponded sediment fill (200 - 400 ms thick; Fig. 9). The minimum depths of the first three peaks on this profile range from 3600 to 3800 m while that of the fourth (outermost, between SP 2400 - 2750) is 3000 m. The intervening basins are at apparently random depths between 4125 and 4420 m below sea level.

The third level is separated from the second by a NW-trending 15 km-wide linear trough 4760 m deep containing 700 ms of ponded sediment. This level is approximately horizontal over a distance of 54 km to the end of the profile (SP 1001 - 2075) with a variable depth of 4575 - 4650 m and a cover of 100 - 200 ms of draped and ponded sediment. There is, however, relief on the basement reflector of up to 1000 m, ranging from a low of 5250 m at SP 2250 in the axis of the trough, to an exposed basement peak high of 4125 m at SP 1350, midway across the level.

Brief comments on UNCLOS parameters: An innermost FoS could be identified at the inner edge of the upper terrace at SP 6630 (3220 m water depth; Fig. 9) on the trend of the most westerly FoSs identified on previous data. A second potential FoS occurs at the inner edge of the second level at SP 4260, at 4130 m water depth. An outer and most likely position for the FoS at SP 2400, in 4750 m water, is identified along the trend of positions determined from existing data prior to this survey. There are no positions of 2500 m water depth on the profile; the expected closure of 2500 m was not encountered.

NZ-G

Objective: Profile NZ-G was planned to extend 324 km down a NE-SW trending ridge projecting from the eastern flank of the TKR into the SFB (Fig. 1). The objective of the line was to show that the ridge is a natural component of the TKR, and to test for a possible FoS position at about 175°40'E 28°S. The line was designed to constrain the position of the 2500 m isobath on the main part of the TKR, and also provide good quality bathymetry for a large isolated closure of the 2500 m isobath on a high at the outer end of the ridge. If the data show that the ridge and its prominent outer high are a natural prolongation off the TKR, it may define an isobath cut-off in the South Fiji Basin further northeast, beyond any 350 n mile cut-off.

Line Description: The southwestern end of the profile (SP 7340) lies west of the crest of the TKR in 1800 m water depth (Fig. 10). The crest comprises two 600 m-deep peaks, 9 km apart at SP 7050 and 7230, separated by a depression 1200 m deep. From the eastern peak, the slope descends steadily for 82 km to a depth of 3375 m at SP 5400, crossing two small basement peaks centred at SP 6725 and 5450. The slope is covered with sediment typically less than 400 ms thick. Between SP 5400 and 3650 the seabed has a very gentle slope, dropping only 300 m in 87 km. Across this section, two 37 km-wide basins containing up to 600 ms of sediment are separated by a 12 km-wide basement high that reaches a minimum water depth of 3150 m at SP 4525.

A very large seamount, 118 km wide, with a total relief of about 4 km, dominates the northeastern end of the profile between SP 3560 and 1200 (Fig. 10). The flanks of the seamount are almost completely devoid of sediment (< 100 ms in small pockets). In contrast, the almost flat topped, 15 km-wide crest of the seamount between SP 2120 and 1820 is covered by sediment (potentially limestone) up to 400 ms thick. Over the northeastern 5 km of the profile, from the outer edge of the seamount to the end of line at SP 1001, the seabed is flat, horizontal, 4725 m deep, and is underlain by up to 500 ms of sediment.

Brief comments on UNCLOS parameters: An innermost FoS occurs at SP 5190 (3525 m water depth), at the western edge of the wide, almost flat sedimentary basin (Fig. 10). A second potential FoS occurs near the western edge of a large seamount, at SP 3560 (3975 m water depth), and a third possible FoS occurs at the eastern edge of the same seamount at SP 1200 (4725 m water depth), on the edge of the SFB. These three positions are consistent with pre-survey identifications from existing data, but given the basal location and water depth of the outermost FoS pick, it is considered to be the most plausible. Three positions of 2500 m occur on the profile: SP 6520 on the main body of the TKR, and SP 2745 and 1400 on either flank of the large seamount.

NZ-H

Objective: Profile NZ-H was planned to extend for 271 km from the end of the Australian line LHRNR-D, on the crest of the TKR, eastward into the southern part of the SFB (Fig. 1). The transect lies south of the prominent ridges that lines NZ-D to NZ-G are designed to image and test for prolongation. Line NZ-H was designed to provide constraints on the 2500 m isobath on the TKR, cross an isolated high of about 2500 m depth near 175°E, and test the sediment thickness beyond the FoS which was expected to lie between 174°E and 175°E. Sediment thickness was anticipated to be important on this line, as thickness generally increases towards the southern part of the basin.

Line Description: The western end of the line at SP 8269 lies at about 1500 m water depth on the eastern edge of an exposed seamount on the crest of the TKR (Fig. 8). This position represents the eastern end of AGSO line LHRNR-D. The eastern slope descends across a basin containing up to 700 ms of sediment, between SP 7830 and 8220. The basin sediment thins significantly against the crestal flank of the TKR, which may reflect erosion or non-deposition because of a current. Between SP 7830 and 7560 is a volcanic seamount, reaching a minimum water depth of 1610 m at SP 7730. East of this seamount the slope descends across a 43 km-wide, 3300 m-deep basin containing up to 1.1 s of sediment. Beneath the lower slope east of the basin is a double-peaked, 35 km-wide seamount complex that reaches a minimum water depth of about 710 m. From the outer edge of this complex, the western 195 km of the SFB floor slopes gently down from 3975 m at the inner edge of the basin (SP 5950) to 4350 m at the outer end of the line.

The smooth basin floor is interrupted only by an isolated, 3260 m-deep seamount centred on SP 4840, and the crest of a second, buried basement high at SP 2930, which projects above the surrounding seafloor (as indicated by side echoes not illustrated here; Fig. 8). The depth of the seabed on either side of the seamount at SP 4840 differs by about 70 m. Sediment thickness beneath the SFB floor ranges from zero to at least 1.2 s. A possible normal fault deforms the basement and part of the sedimentary cover at SP 1350.

Brief comments on UNCLOS parameters: There are three crossings of the 2500 m isobath on this profile (Fig. 8). The westernmost occurs at SP 7620, on the eastern flank of the main body of the TKR. The other two occur at SP 6630 and 6420, on either flank of the prominent seamount complex on the lower slope. None of these positions is relevant to New Zealand's potential claim, as the region lies well inside the 350 n mile cut-off. However, they would be relevant to any Australian claim in this area as the most likely Hedberg point (H1; Fig. 8) lies beyond an Australian 350 n mile cut-off, but inside the isobath cut-off as measured from the seamount complex. The most likely FoS occurs at SP 5950, at the 3975 m-deep, outer edge of the double-peaked seamount complex. This position would extend the innermost Hedberg Line on pre-cruise planning charts by about 20 km to the east. Only about 300 ms of sediment occurs at the Hedberg point (H1, at SP 2730), but this thickness increases to greater than 1 s over the next few tens of kilometres. An outermost FoS might be sustainable at SP 4650, at the edge of one of the outer seamounts. At the Hedberg point with respect to this position (H2, at SP 1460), about 1 s of sediment is present.

NZ-I

Objective: Profile NZ-I is the southernmost and longest of the lines commissioned by New Zealand, and lies close to New Zealand's EEZ defined from the Three Kings Islands. The line was planned to extend 446 km eastwards from the axis of the TKR, across the southern part of the SFB (Fig. 1), to the edge of New Zealand's EEZ defined from the Kermadec Islands. The profile was designed to cross two prominent seamounts, at least one of which was expected to lie inside the FoS, which appears to lie between 174°30'E and 175°30'E. Existing data indicated that sediment thickness should exceed 1 km beyond the FoS, which might facilitate a claim based on the 1 % sediment thickness formula.

Line Description: From SP 1001 on the central crest of the TKR, the first 65 km of the profile across the upper part of the ridge traverses three peaks at about 530 m water depth, separated by basins 900 - 2020 m deep (Fig. 10). The peaks are 2.5 - 7.5 km wide and are flat topped, suggesting a former period of wave-base planation. One of the intervening basins centred at SP 1630 contains up to 680 ms of sediment. From the outer edge of the eastern flat-topped peak at SP 2280, an irregular slope descends over a distance of 87 km to a water depth of 3900 m at SP 4025. On the slope are two 25 km-wide basins that contain up to 800 ms of sediment, and two prominent seamount peaks. The seamount peaks rise about 1500 m above the perched sedimentary basins, and reach minimum water depths of 1100 m (SP 3040) and 2025 m (SP 3810) respectively.

From SP 4025 to the end of line at SP 9820 the seabed is, on average, smooth and sub-horizontal, increasing in depth from 3900 m to 4125 m (Fig. 10). This surface represents the floor of the SFB, which on this line is interrupted by a large (32 km wide, > 3 km high) seamount that reaches a minimum water depth of about 940 m at SP 6000. On either side of the seamount the basin floor is underlain by sediment up to 1.3 s thick (typically 0.8 - 1.0 s). Aprons of probably volcaniclastic debris occur in the lower part of the sedimentary succession, adjacent to the seamount.

Brief comments on UNCLOS parameters: There are seven positions of 2500 m water depth on the profile (Fig. 10). The westernmost, at SP 2650, lies on the continuous isobath of the main part of the TKR. The six other positions occur on the flanks of three prominent seamounts. An innermost, and probably most plausible, FoS is identified at SP 4025 in 3900 m water depth at the outer edge of the second seamount. The outermost (third) seamount does not appear to be included within the slope, thus eliminating the outermost potential Hedberg Line at this latitude as shown on pre-survey planning maps. About 1 s sediment thickness is confirmed beyond the Hedberg point, so a claim based on the 1 % sediment thickness formula is possible, if sufficiently high velocities are confirmed by the sonobuoy refraction data obtained. Up to 1.3 s sediment thickness at the outer end of the line may be important for a potential New Zealand sediment thickness claim west of the Colville Ridge (Fig. 1).

OPERATIONAL HIGHLIGHTS

- The first use of an onboard seismic pre-processing system, which was capable of applying sophisticated filtering to shot records, thus providing assurance of the quality of data being acquired in marginal weather conditions. This could not be done in real time, but in a sufficiently timely manner to allow for re-shooting of a section of line, should that be necessary. As the weather was favourable for most of the survey time, this service was only sparingly used. As an added bonus, seismic profiles were processed to brute stack level, a huge advance on anything previously attempted and potentially a huge saving in final processing cost.
- The first use of a compressed-air sonobuoy launcher, using a design developed onboard the US ship *S.P. Lee* and brought to fruition, through several phases of R&D, by the AGSO gun mechanics. This provided successful launches to about 30 - 50 m off the side of the ship, minimising the chance of the sonobuoy, with its trailing hydrophone, fouling the streamer cable and/or tail buoy.
- The first use of a new type of magnetometer utilising the Overhauser principle; all previous devices have been of the proton precession type. The new instrument showed promise in

giving excellent, noise-free results while working, but proved to be somewhat fragile in a number of design areas.

- The extreme usefulness of the processed satellite gravity image, which in this poorly-surveyed, deep-water environment proved to be much more accurate, at least in a qualitative sense, than any bathymetric charts available.

CONCLUSIONS

The data collected on this survey have confirmed the view that the area east of Norfolk Island is morphologically complex, to the extent that we have not identified any unequivocal picks of FoS between the Norfolk Ridge and the Three Kings Ridge. It appears that Australia may be able to claim prolongation from Norfolk Island, on the Norfolk Ridge, to and beyond the Three Kings Ridge, via the complex saddle and ridge area that separates the North and South Norfolk Basins. It would also appear that further surveying of the same type, i.e. individual seismic/bathymetric profiles, is not a very efficient way of clarifying the issue. A large scale multibeam, swath-mapping survey is probably the most effective way of providing the much needed detail on the bathymetric complexities of the area, and the way the various provinces connect to each other.

Unfortunately, the rules and definitions of Article 76 of UNCLOS are not readily applied to a margin such as exists here. However, when consideration is given to the 'basal' FoS position as specified in Article 76, a somewhat clearer picture emerges of prolongation to the east of the Norfolk Ridge. At a latitude of about 30° S, the Norfolk and Three Kings Ridges appear to connect through an area of complex, rugged bathymetry at an average depth of about 2500 m (Lines LHRNR-D and NZ-H). Although there are many changes in slope and potential FoSs through this area, the 'basal' FoS is clearly east of the Three Kings Ridge, on the margin of the South Fiji Basin, at a depth of about 4000 m (Line NZ-H). Under Article 76, such an interpretation would imply connectivity and natural prolongation through this area from the Norfolk Ridge, across the Three Kings Ridge, and down into the South Fiji Basin, bearing in mind that natural prolongation from New Zealand along the Three Kings Ridge is also demonstrable.

The Cook Fracture Zone appears to be a much more significant boundary on Line NZ-D than on LHRNR-C. On the former, it could represent a valid FoS partly because of its proximity to the Three Kings Ridge and partly because of its absolute depth. On the latter line, the CFZ neither represents such a distinct boundary, nor does it reach as great a depth as on the New Zealand line.

FoS picks on the New Zealand lines radiating out from the Three Kings Ridge towards the South Fiji Basin are somewhat more simple. There is generally a clear edge-of-abyssal-plain pick, which represents the most distal possible FoS position, but other more proximal positions occur to the west of seamount/ridge complexes on the southwest margin of the SFB. Probably the clearest FoS picks would have to be the ones on either flank of the New Caledonia Basin on Line LHRNR-B.

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APPENDIX 1 – ARTICLE 76

United Nations Convention on the Law of the Sea

Article 76
Definition of the continental shelf

1. The continental shelf of a coastal State comprises the seabed and subsoil of the submarine areas that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles from the baselines from which the breadth of the territorial sea is measured where the outer edge of the continental margin does not extend up to that distance.

2. The continental shelf of a coastal State shall not extend beyond the limits provided for in paragraphs 4 to 6.

3. The continental margin comprises the submerged prolongation of the land mass of the coastal State, and consists of the seabed and subsoil of the shelf, the slope and the rise. It does not include the deep ocean floor with its oceanic ridges or the subsoil thereof.

4. (a) For the purposes of this Convention, the coastal State shall establish the outer edge of the continental margin wherever the margin extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by either:

   (i) a line delineated in accordance with paragraph 7 by reference to the outermost fixed points at each of which the thickness of sedimentary rocks is at least 1 per cent of the shortest distance from such point to the foot of the continental slope;

   or

   (ii) a line delineated in accordance with paragraph 7 by reference to fixed points not more than 60 nautical miles from the foot of the continental slope.

   (b) In the absence of evidence to the contrary, the foot of the continental slope shall be determined as the point of maximum change in the gradient at its base.

5. The fixed points comprising the line of the outer limits of the continental shelf on the seabed, drawn in accordance with paragraph 4 (a) (i) and (ii), either shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured or shall not exceed 100 nautical miles from the 2,500 metre isobath, which is a line connecting the depth of 2,500 metres.

6. Notwithstanding the provisions of paragraph 5, on submarine ridges, the outer limit of the continental shelf shall not exceed 350 nautical miles from the baselines from which the breadth of the territorial sea is measured. This paragraph does not apply to submarine elevations that are natural components of the continental margin, such as its plateaux, rises, caps, banks and spurs.

7. The coastal State shall delineate the outer limits of its continental shelf, where that shelf extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured, by straight lines not exceeding 60 nautical miles in length, connecting fixed points, defined by coordinates of latitude and longitude.

8. Information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured shall be submitted by the coastal State to the Commission on the Limits of the Continental Shelf set up under Annex II on the basis of equitable geographical representation. The Commission shall make recommendations to coastal States on matters related to the establishment of the outer limits of their continental shelf. The limits of the shelf established by a coastal State on the basis of these recommendations shall be final and binding.

9. The coastal State shall deposit with the Secretary-General of the United Nations charts and relevant information, including geodetic data, permanently describing the outer limits of its continental shelf. The Secretary-General shall give due publicity thereto.

10. The provisions of this article are without prejudice to the question of delimitation of the continental shelf between States with opposite or adjacent coasts.

APPENDIX 2 – INFORMAL TERMS RELATING TO ARTICLE 76

Application of Article 76 of UNCLOS (Appendix 1) raises several concepts and terms which will be referred to frequently in interpretations of seismic/bathymetric survey lines for the purposes of LCS definition. Following are simplified definitions of the more important terms that we commonly use.

Firstly, a *Hedberg arc* may be drawn, with a radius of 60 n miles, from an interpreted FoS position. Where this arc intersects the seaward extension of the survey line is called the *Hedberg point.* With a series of FoS positions established around a continental margin, at a spacing of less than 120 n miles, a series of intersecting Hedberg arcs may then be constructed. Clearly, as the spacing between survey lines (and therefore, the FoS positions) decreases, the envelope of the intersecting Hedberg arcs approaches a 60 n mile buffered locus of the FoS, except in some cases where the latter contains embayments. This is part of the reason for AGSO's 'safe minimum' approach, where we aim to space survey lines ~30 n mile apart, where logistically possible. The final outcome, the true *Hedberg Line* (the informal name for the line that defines the outer edge of the 'legal' continental margin, as contained in Article 76, paragraph 4(a)(ii)), is constructed by joining selected points on the Hedberg arcs by straight lines, not more than 60 n mile long. This would normally be done in a manner such as to maximise the size of the enclosed 'legal' continental margin. This true Hedberg Line will normally only intersect the survey line at the Hedberg point where the locus of the FoS is a straight line, which is unusual in the context of LCS, since it is normally generated by irregularly shaped marginal plateaus or islands.

Secondly, a *Sediment Thickness point* may be determined, by interpretation of a seismic survey line (or possibly by drilling), where the 1% sediment thickness criterion is satisfied. In contrast to the Hedberg arc, this is strictly a single point, which may be joined to adjacent Sediment Thickness points to form the *Sediment Thickness Line* (the informal name for the line that defines the outer edge of the 'legal' continental margin, as contained in Article 76, paragraph 4(a)(i)), or to selected points on Hedberg arcs, again by straight lines, not more than 60 n mile in length.

Finally, the fixed points (not more than 60 n mile apart) comprising the line which defines the outer limits of the LCS, may not lie beyond one or other of two cut-offs. The first cut-off is 350 n mile from the baseline (informally called the *350 n mile cut-off line*), and the second is 100 n mile beyond the 2500 m isobath (informally called the *isobath cut-off line*). The former is purely a geometrical construction from the Territorial Sea baselines, whereas the latter depends on definition of the 2500 m isobath.

APPENDIX 3 – SONOBUOY DEPLOYMENTS

Twenty five military type sonobuoys were loaded on board at the beginning of the cruise. Twenty four were deployed during the cruise.

The first sonobuoy sank without transmitting, and there was concern that others could fail as well. Most subsequent sonobuoys were opened and their salt-water batteries tested by immersion in salt water on deck before being launched over the side. This meant that the sonobuoy antenna and hydrophone string was already released when the sonobuoy was launched. During the course of the survey, no other sonobuoys were found to have defective batteries.

The success rate using this method was nevertheless low. Not knowing if the reason for the failures lay with the sonobuoys or the 4 km-long trailing gear that could potentially snag them, two courses of action were taken. (i) Every sonobuoy was dismantled prior to launch and its scuttling device (usually located behind the battery pack) sealed with epoxy to prevent premature shut down of the device. (ii) A compressed-air launcher was constructed on board that would fire sonobuoys well to the side of the ship and clear of the gear. The launcher, improvised from a sonobuoy liner and packing tube and using compressed air from the air gun manifold, was based on specifications obtained by e-mail from the US Geological Survey and Lamont Doherty Earth Observatory.

Despite the modifications to the scuttling port, and pre-launch triggering of the sonobuoy, approximately half of the hand-launched instruments failed within 10 or 15 minutes of launch.

The first air-launched sonobuoy was badly aimed and the transmitter was disabled when it hit the overhanging helicopter deck, but all subsequent air-launched sonobuoys worked well, clearing the trailing gear and transmitting an acceptable signal. The air-launched instruments were not triggered before being loaded into the launcher. The plastic launcher performed well, but a metal tube was ordered from NIWA to build a more robust launcher for the second cruise. Use of the compressed-air launcher is strongly recommended for the second cruise. Continued plugging of the scuttling ports is an advisable though probably not essential option.

RECORD OF DEPLOYMENTS

(F) = failed

LHRNR-C -

(F) sonobuoy # au1, channel ?, hand-launched at 264/1235 in metal canister, no signal, presumed sunk.

(F) sonobuoy # au2, channel ?, hand-launched at 265/0229 after removing from canister and deploying on deck in salt water to test hydrophone. Hydrophone set to 60 ft., no signal.

(F) sonobuoy # au3, channel 12, hand-launched to leeward at 269/0425 in same way as # au2. Hydrophone set to 60 ft, stopped transmitting abruptly

(F) sonobuoy # au3, channel 12, hand-launched to leeward at 269/0425 in same way as # au2. Hydrophone set to 60 ft, stopped transmitting abruptly after 10 min., snagged by bird 1.5 km astern on streamer (as shown by presence of hydrophone wire when streamer retrieved).
sonobuoy # au4, channel 12, hand-launched to leeward at 269/0451 in same way as # au2. Hydrophone set to 60 ft, good, transmitted > 1hr 30min

NZ-G -

sonobuoy # nz1, channel 11, dismantled, plugged scuttling port with silastic, deployed on deck, tested signal, hand-launched without canister at 277/1054. Hydrophone set to 60 ft, good, transmitted approx 3hr 20min. As a matter of interest, this sonobuoy was dated 1987.
(poss F) sonobuoy # nz2, channel (not noted, probably 11), plugged scuttling port with silastic, deployed on deck, tested signal, hand-launched without canister to leeward at 277/1918. Hydrophone set to 60 ft., initially good but noise bursts began after approx 1 hr, drowning signal out within 10 min, transmission ended 10 min later. Continued carrier-wave noise.

NZ-I -

(F) sonobuoy # nz3, channel 12, plugged scuttling port with silastic, deployed on deck, tested signal, hand-launched without canister to leeward at 279/1640. Hydrophone set to 60 ft., noisy, signal deteriorated abruptly, faded quickly in noise and failed within 13 minutes.
sonobuoy # nz4, channel 11, deployed on deck, tested signal, hand-launched without canister to leeward at 279/1709. Hydrophone set to 60 ft., good, transmitted > 1hr 40min
sonobuoy # nz5, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched without canister at 280/0429. Hydrophone set to 60 ft., very noisy but possibly salvageable, transmitted > 3hr 10min.
sonobuoy # nz6, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 280/1337. Hydrophone set to 60 ft., good, transmitted > 3hr 10min.

NZ-H -

sonobuoy # nz7, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 281/1739. Hydrophone set to 1000 ft, excellent signal, transmitted > 3hr.
(F) sonobuoy # nz8, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 283/0100. Hydrophone set to 1000 ft, failed, signal ended abruptly after 10 min. Continued receiving RF transmission, suggests loss of hydrophone.
sonobuoy # nz9, channel 11, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 283/0137. Hydrophone set to 1000 ft, good, recorded for > 3 hr.
(F) sonobuoy # nz10, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 283/0950. Hydrophone set to 1000 ft, failed, signal ended abruptly after 10 min.

sonobuoy # nz11, channel 10, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 283/1017 Hydrophone set to 1000 ft, good, recorded for > 3 hr.

LHRNR-D -

(F) sonobuoy # au5, channel 12, plugged scuttling port with epoxy, hydrophone set for 1000 ft, reassembled and fired to leeward from high-pressure launcher at 283/2305, glanced off underside of helicopter deck, landed 40 m away, antenna deployed but radio dead.

sonobuoy # au6, channel 11, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 283/2315. Hydrophone set to 1000 ft, good, cleared tail buoy, good record for > 1 hr (still recording at 284/002).

LHRNR-B -

(F) sonobuoy # au7, channel 12, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 286/2103. Hydrophone set to 1000 ft, good signal but failed after 1/2 hour, noisy RF but no signal.

sonobuoy # au8, channel 10, plugged scuttling port with epoxy, deployed on deck, tested signal, hand-launched to leeward without canister at 286/2139. Hydrophone set to 400 ft, noisy.

sonobuoy # au9, channel 12, plugged scuttling port with epoxy, hydrophone set for 1000 ft, reassembled and fired to leeward from high-pressure launcher at 289/2057, good record for > 3 hr.

(F) sonobuoy # au10, channel 12, plugged scuttling port with epoxy, reassembled and hand-launched to leeward without canister at 290/0430. Hydrophone set to 1000 ft, failed after 10 min.

sonobuoy # au11, channel 2, plugged scuttling port with epoxy, hydrophone set for 1000 ft, reassembled and fired from high-pressure launcher at 290/0450, good record for > 3 hr.

sonobuoy # au12, channel 12, plugged scuttling port with epoxy, hydrophone set for 1000 ft, reassembled and fired from high-pressure launcher at 291/1222, good record for > 2.5 hr.

- sonobuoy # au13, channel 12, plugged scuttling port with epoxy, hydrophone set for 1000 ft, reassembled and fired from high-pressure launcher at 292/1542, good record for > 3 hr.

APPENDIX 4 – CREW LIST

AGSO Crew

Drew Murray	Ship Manager
Norm Johnston	Systems Expert
Mike Sexton	Seismic Processing Expert
Doug Ramsay	LOS Project Representative
Greg Atkinson	Quality Control Expert
Tim Viser	Quality Control Trainee
Paul Attenborough	Shift Leader
Fleur Wiley	Science Technical Officer
Duncan Palmer	Science Technical Officer
David Warren-Smith	Shift Leader
Linda Philippa	Science Technical Officer
Shaun Hazell	Science Technical Officer
Steve Thomas	Electronics Technical Officer
Mick Schade	Electronics Technical Officer
Mark James	Mechanical Technical Officer
Alan Radley	Mechanical Technical Officer
Simon Milnes	Mechanical Technical Officer
Brian Dickinson	Mechanical Technical Officer

New Zealand Representatives

Rick Herzer	Institute of Geological & Nuclear Sciences, Ltd
Phil Barnes	National Institute of Water & Atmospheric Research, Ltd

AMSA Ship Crew

Trevor Walters	Master
Mike Gusterson	First Mate
John Weeks	Second Mate
Ian McCarthy	Chief Engineer
John Scott	Second Engineer
Ian McCulloch	Electrician
Rod Willis	Chief Integrated Rating
John Fraser	Integrated Rating
Tony Dale	Integrated Rating
Ken Lindquist	Integrated Rating
Henk Dekker	Chief Steward
Ken Beu	Cook
Ted Strange	Steward
Steve Stavely	Steward

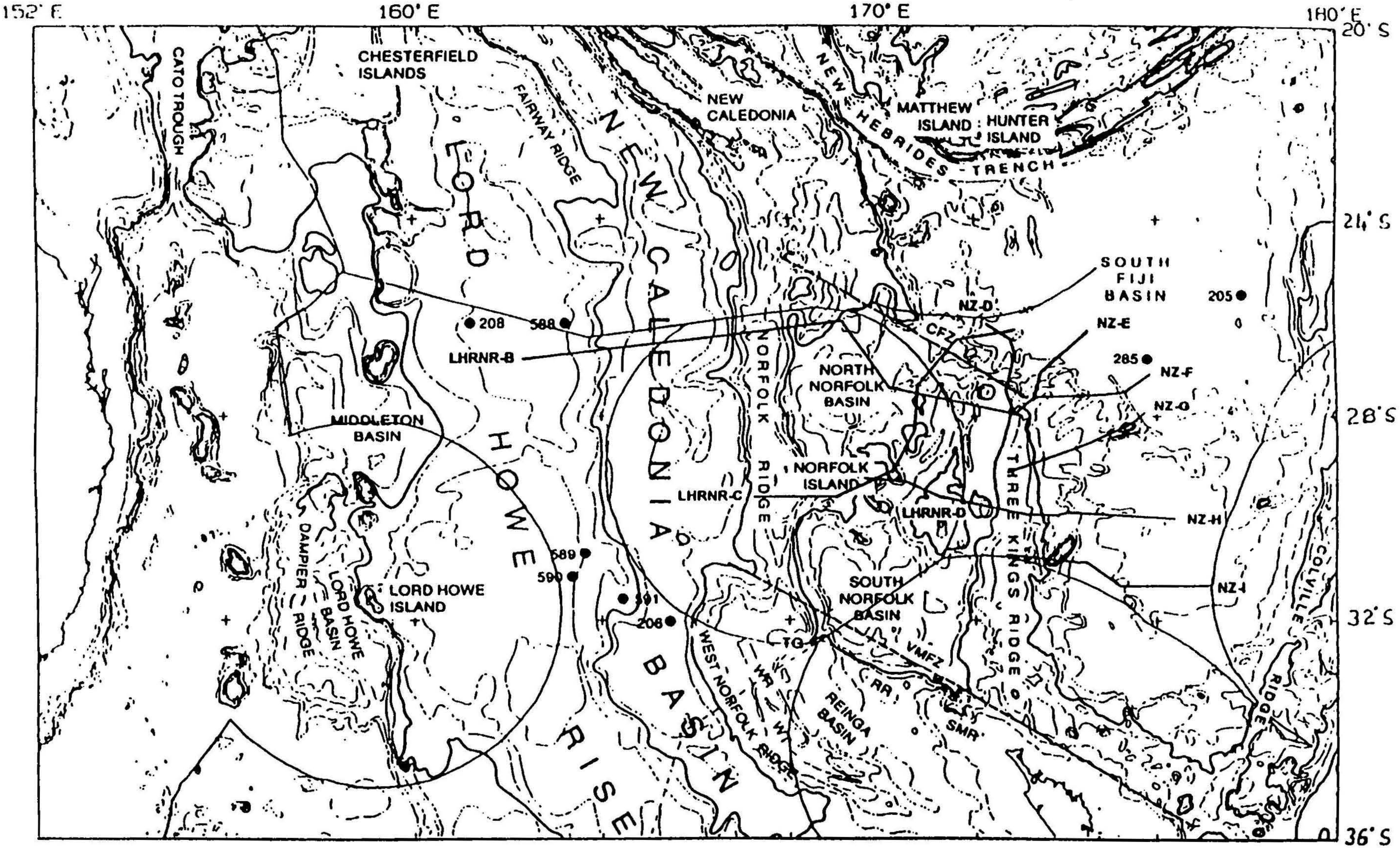


Figure 1. Map of Norfolk Ridge/Three Kings Ridge UNCLOS survey region showing EEZs, survey lines and main morphological features. Dots with numbers represent DSDP drill holes.

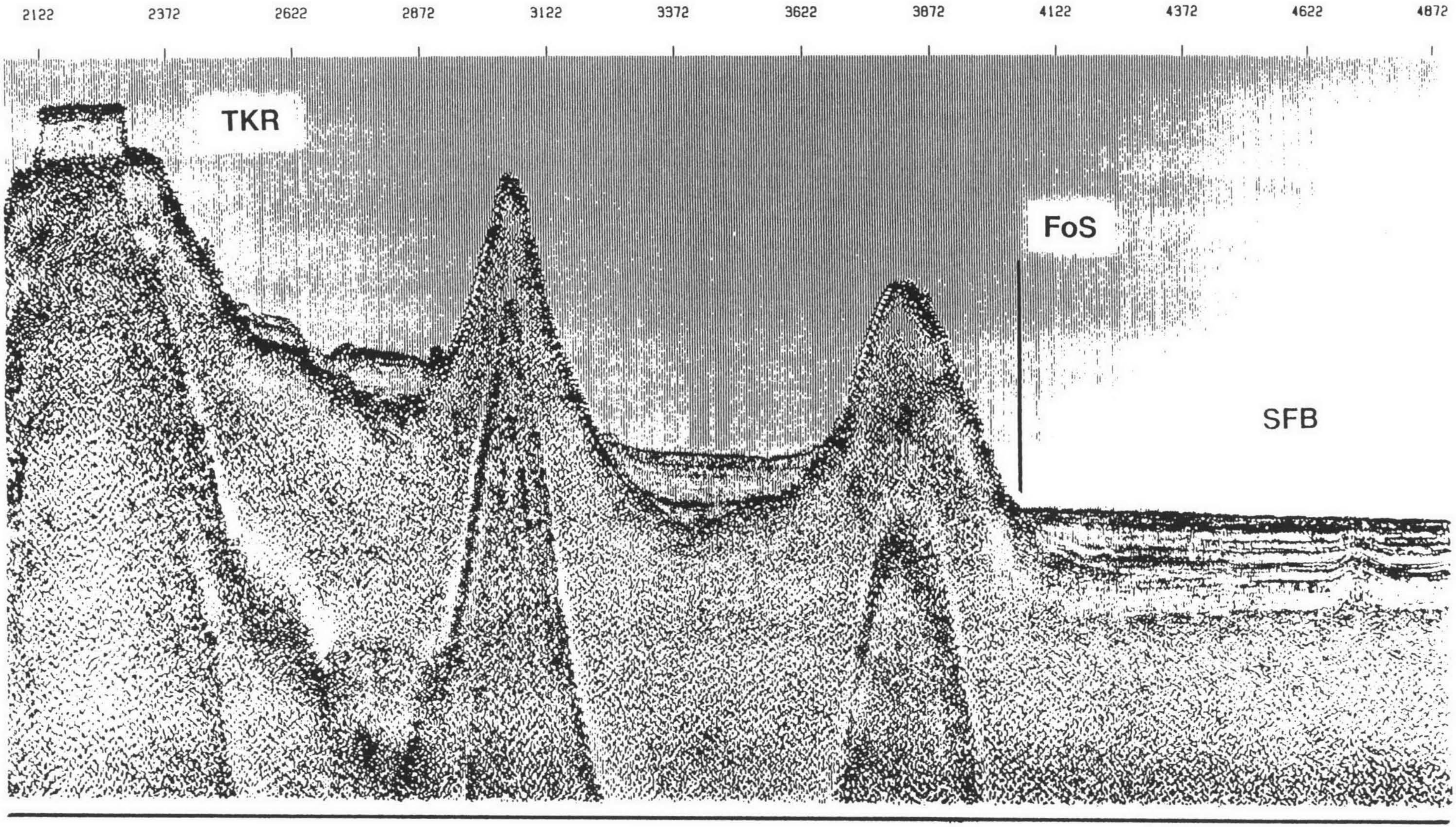


Figure 2. A typical brute stack seismic section (part of line NZ-I) produced on board, showing two volcanic seamounts on the eastern flank of the Three Kings Ridge (TKR), sedimentary layers in the flanking basins, and the most likely foot-of-slope (FoS) position. Relatively thick sediment in the South Fiji Basin (SFB) may be useful for determining the legal Continental Shelf from the 1% sediment thickness principle.

SONOBUOY: NZ-H SP 1139

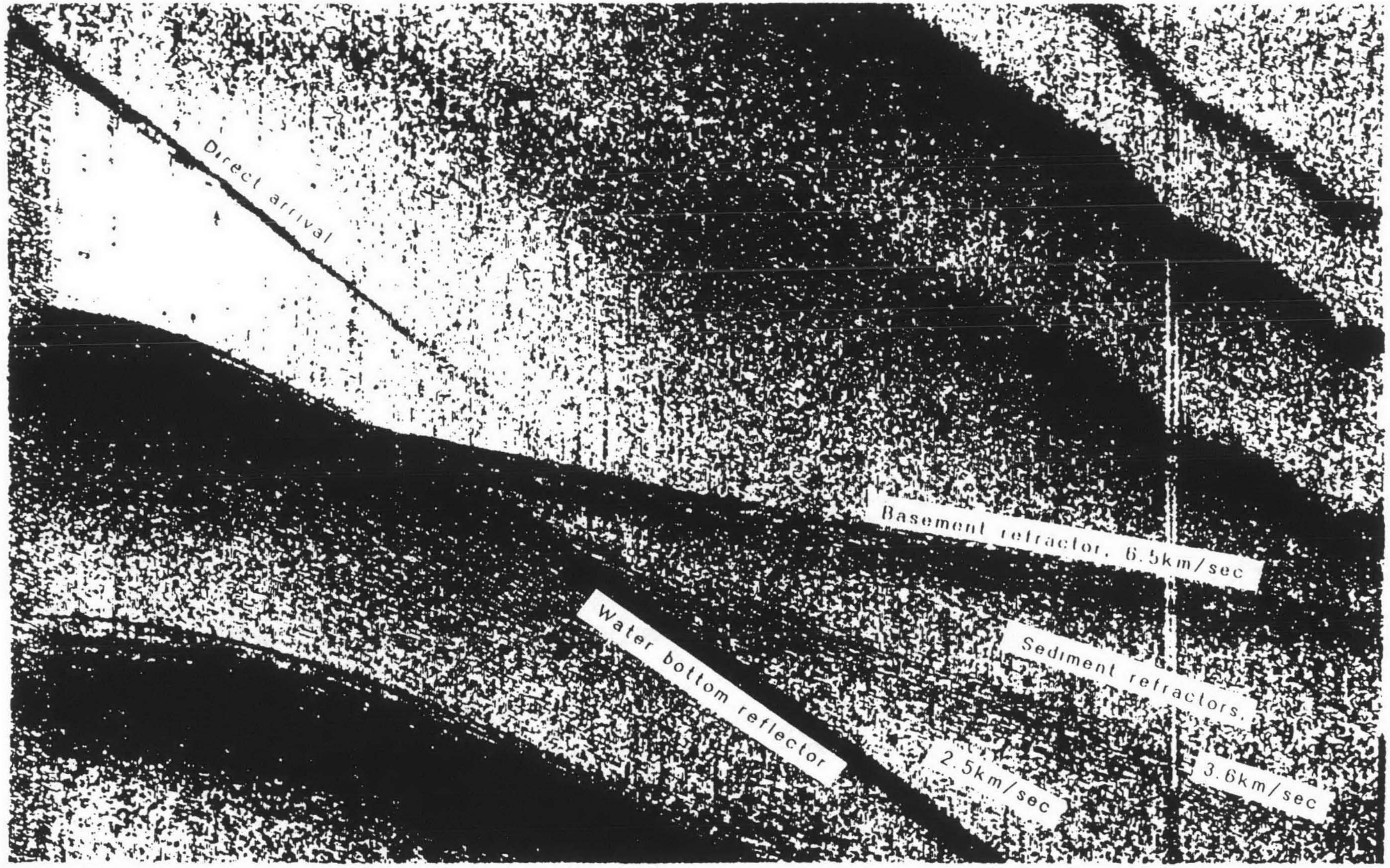
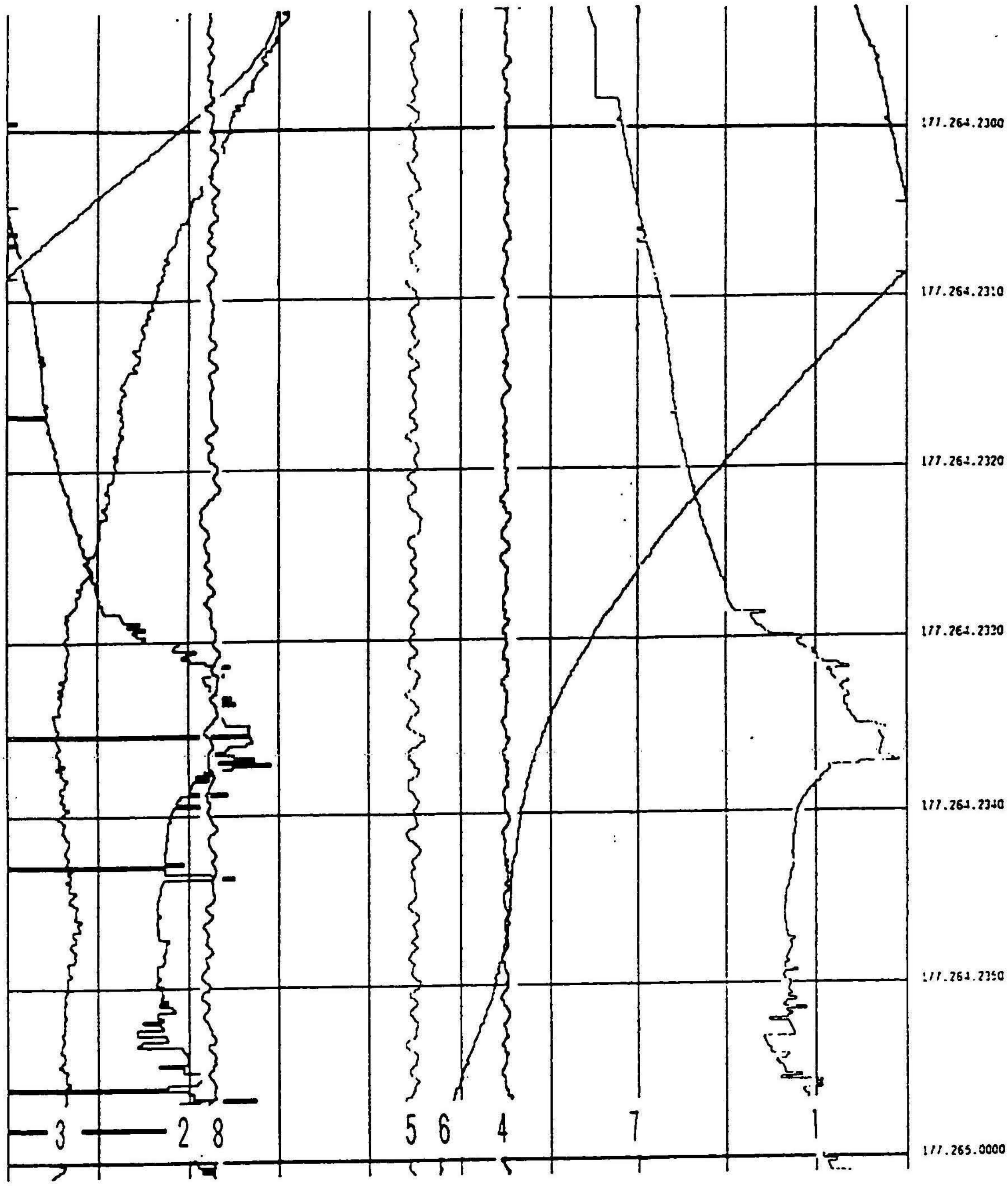


Figure 3. A processed sonobuoy seismic refraction record from line NZ-H east of the Three Kings Ridge. Two sediment-layer acoustic velocities and a volcanic basement velocity were calculated from this profile.



Pen	Chan	Type	Width	Name	Last Value
1	10	1	1000.000000	12 KHZ ECHOSOUNDER	1437.300049
2	11	1	1000.000000	3.5 KHZ ECHOSOUNDER	1436.300049
3	84	1	100.000000	GRAVITY	-1025.119995
4	85	1	1.000000	ACX	0.003100
5	86	1	1.000000	ACY	0.000700
6	88	1	500.000000	MAGNETOMETER	51738.734375
7	6	1	10.000000	SPEED BEST	5.102423
8	7	1	400.000000	COURSE BEST	91.256683

Figure 4. An example of the real-time digital bathymetric and geopotential data print-out.

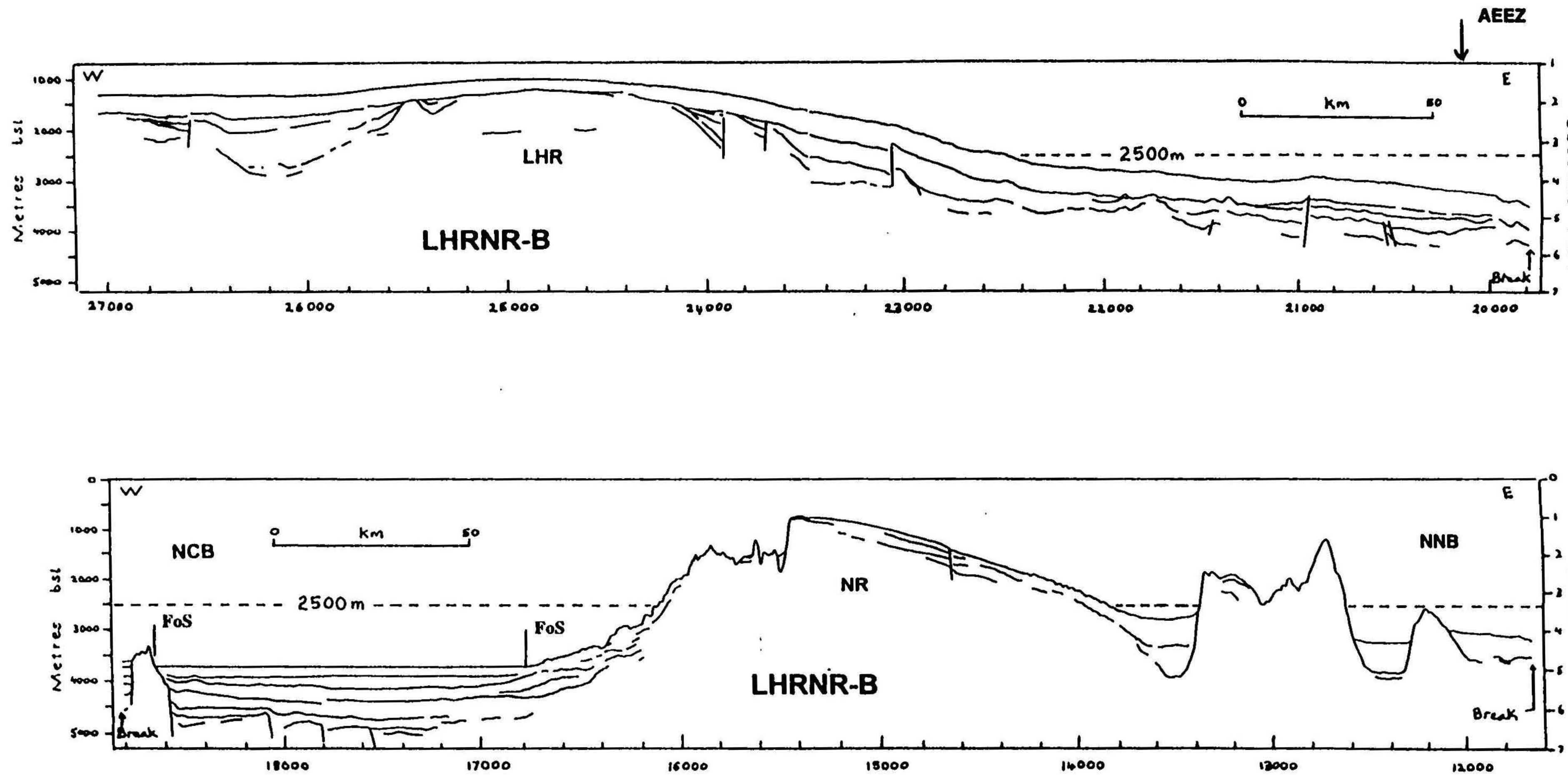


Figure 5. Line drawing interpretations of single trace monitor record of part of seismic profile LHRNR-B, showing the Lord Howe Rise (LHR), the New Caledonia Basin (NCB), the Norfolk Ridge (NR) and the western North Norfolk Basin (NNB). FoS = possible foot-of-slope picks.

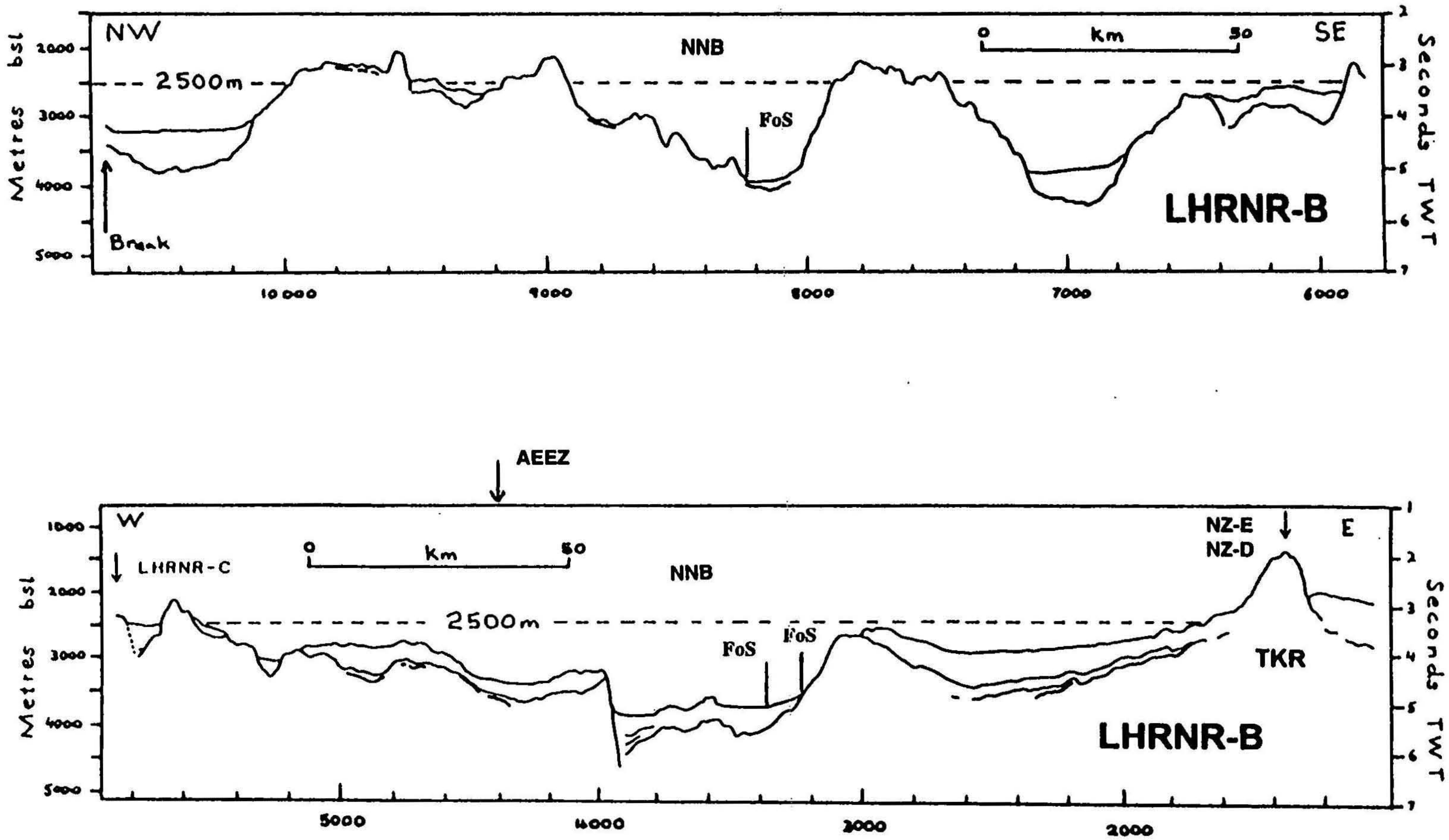


Figure 6. Line drawing interpretations of single trace monitor record of part of seismic profile LHRNR-B, from the central North Norfolk Basin (NNB) to the crest of the Three Kings Ridge (TKR). Possible foot-of-slope (FoS) picks are shown for both the TKR and possible Norfolk Ridge extensions.

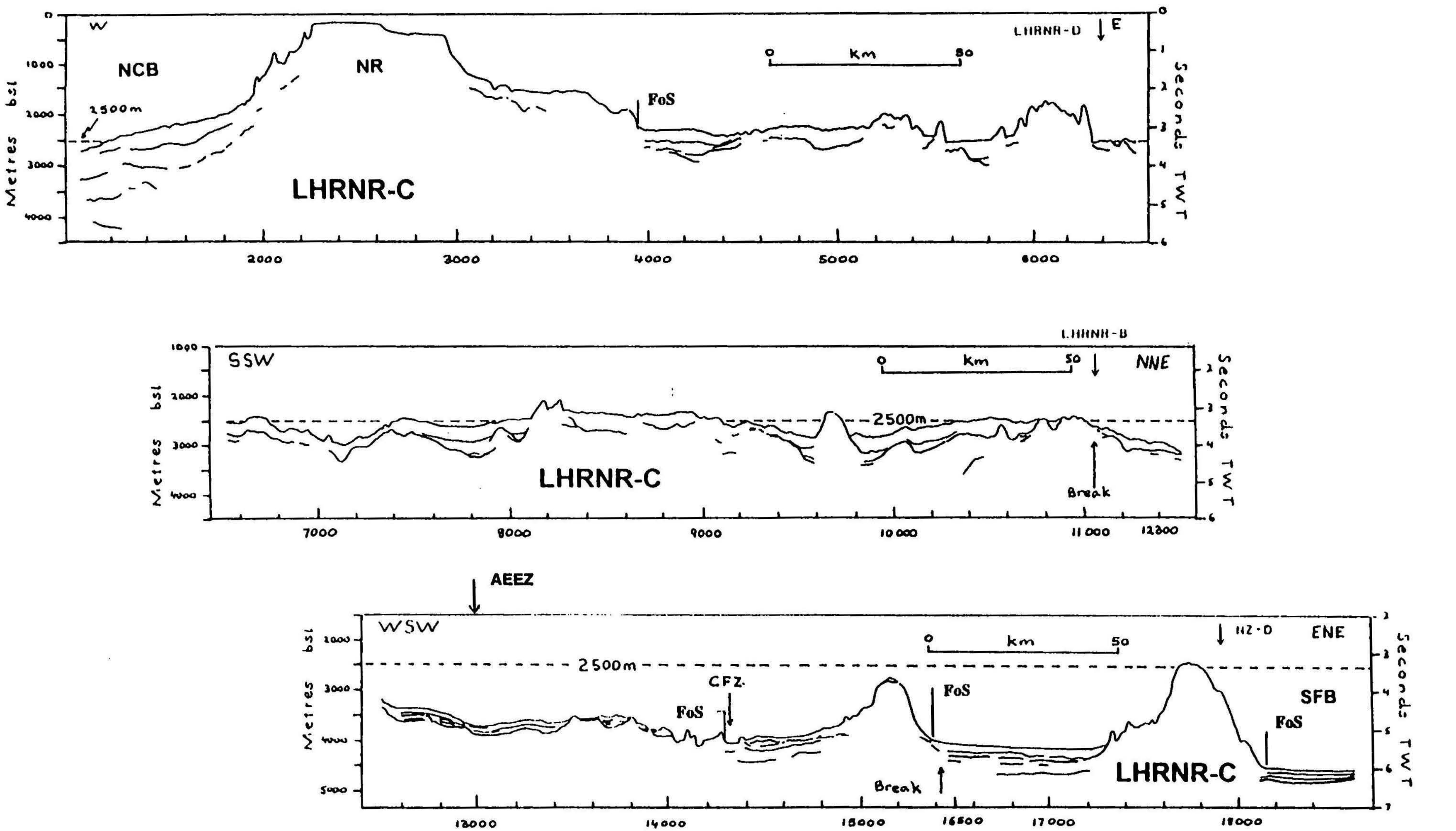


Figure 7. Line drawing interpretations of single trace monitor record of seismic profile LHRNR-C, from the southern Norfolk Ridge (NR) along a line of highs to the southeast of the North Norfolk Basin (NNB) to a region in the South Fiji Basin north of the Three Kings Ridge (TKR). CFZ = Cook Fracture Zone; FoS = possible foot-of-slope picks.

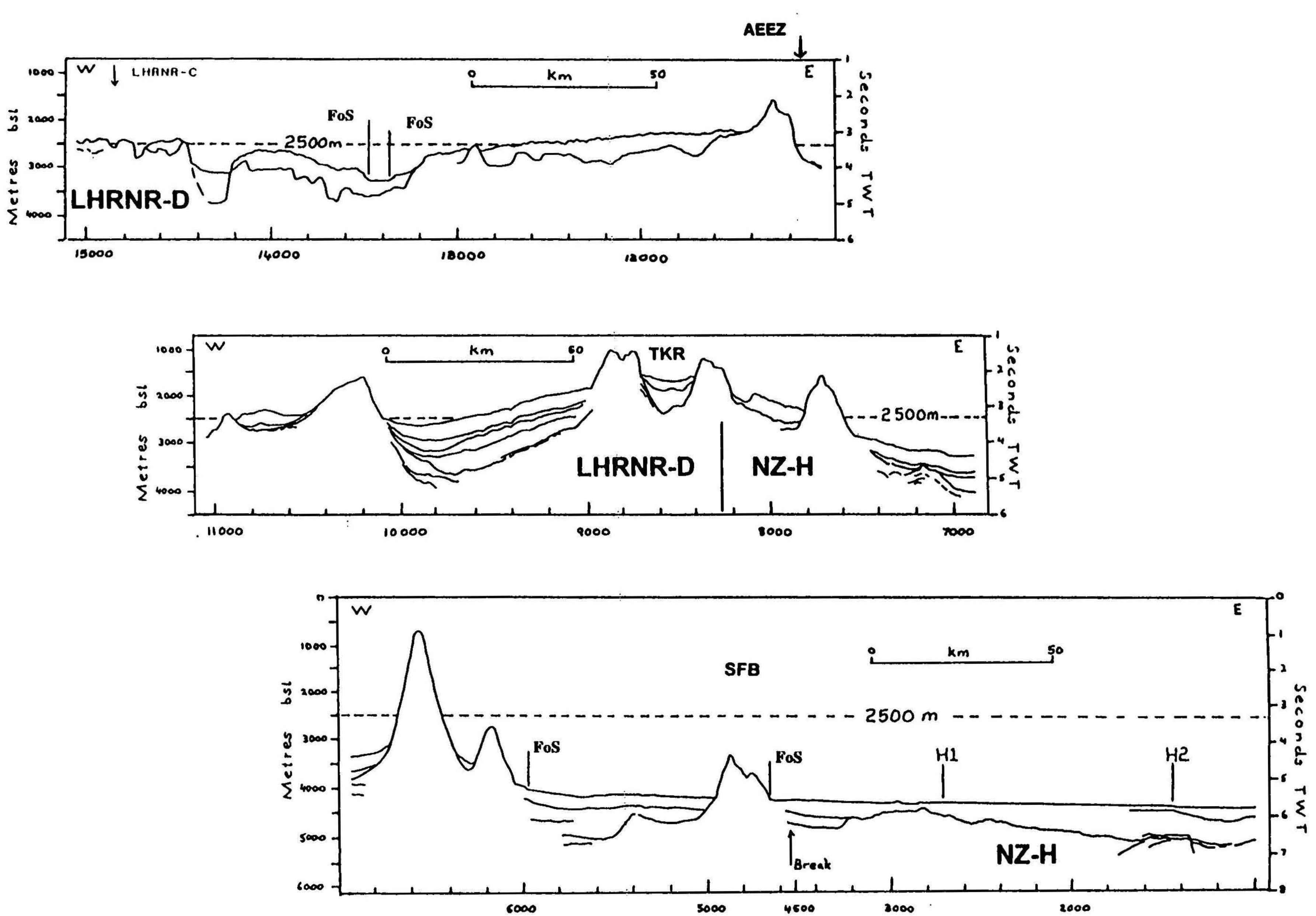


Figure 8. Line drawing interpretations of single trace monitor record of combined seismic profile LHRNR-D and NZ-H from the intersection with line LHRNR-C on the complex saddle area separating the North and South Norfolk Basins, across the Three Kings Ridge (TKR) to the South Fiji Basin (SFB). FoS = possible foot-of-slope picks; H = possible Hedberg point position.

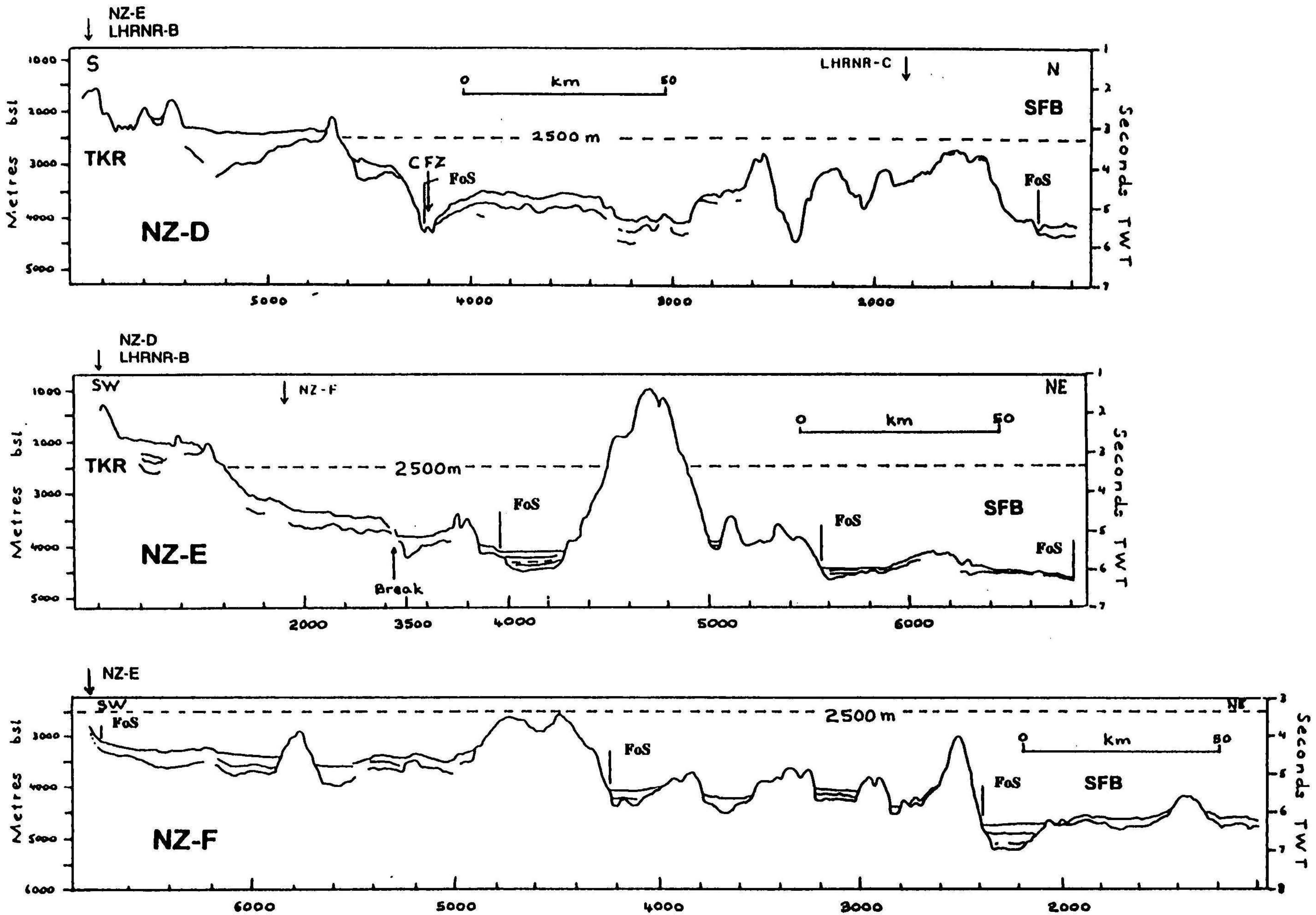


Figure 9. Line drawing interpretations of single trace monitor records of seismic profiles NZ-D, E, and F radiating into the South Fiji Basin (SFB) from the northern end of the Three Kings Ridge (TKR). FoS = possible foot-of-slope picks; CFZ = Cook Fracture Zone.

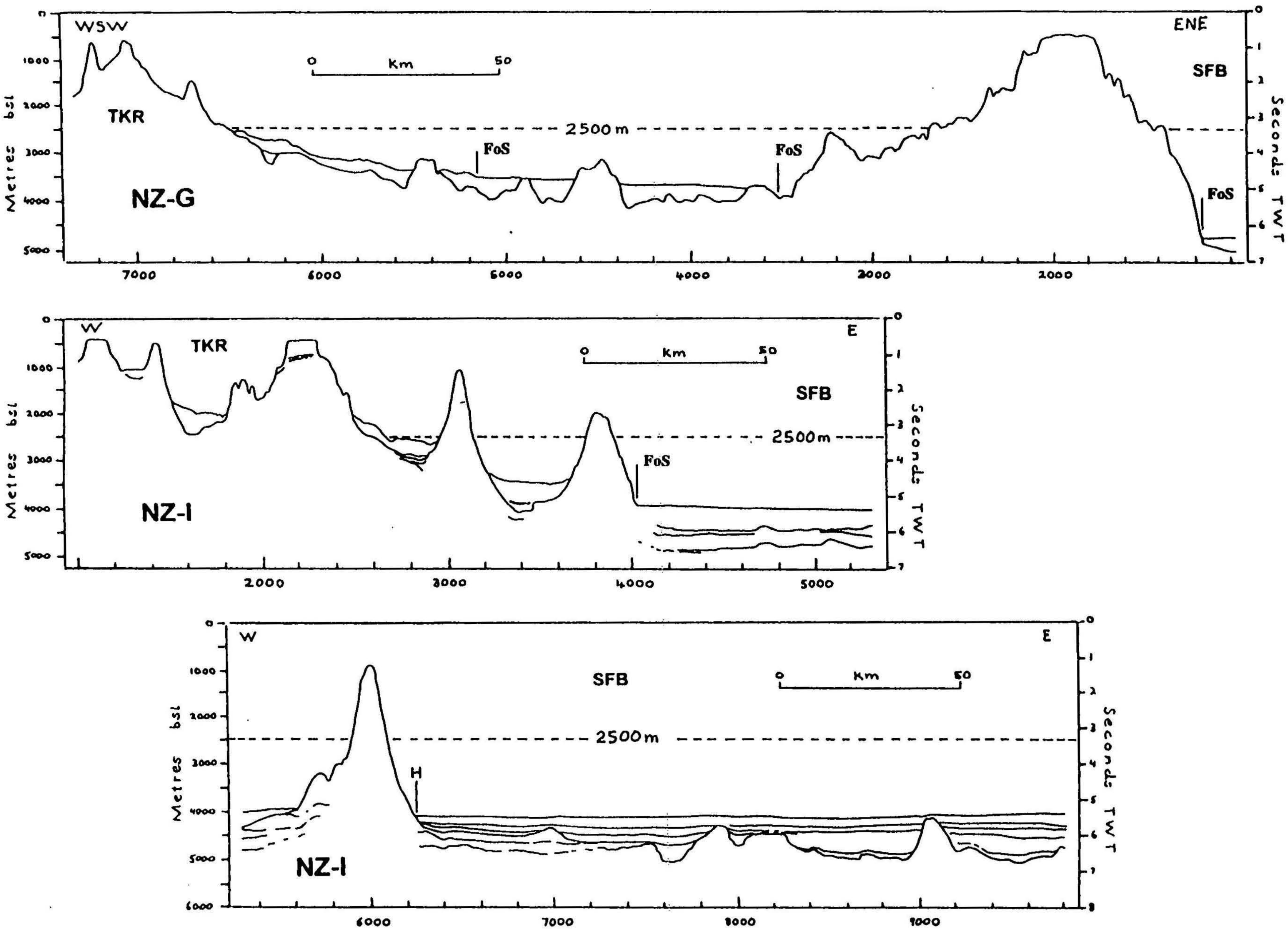


Figure 10. Line drawing interpretations of single trace monitor records of seismic profiles NZ-G and I extending east from the Three Kings Ridge (TKR) into the South Fiji Basin (SFB). FoS = possible foot-of-slope picks; H = possible Hedberg point position.