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SUBMARINE CANYONS ON THE CONTINENTAL MARGIN OF SOUTHEAST AUSTRALIA

by

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SUMMARY

Ten submarine canyons or canyon-like features have been discovered south of Jervis Bay (latitude 35°S) as a result of echo-sounding and seismic profiling of the continental shelf and upper continental slope. The continental slope in this region is steep (4-14°) and related to the slope of the basement. All the canyons head below the shelf break, except Bermagui Canyon which heads 20 m above the shelf break. Ocean sounding data reveal large canyon systems extending to a depth of 4500 m. All the canyons traversed are cut into a thick (300-350 m) sequence of prograding sediments. Nowhere is seismic basement (Palaeozoic) seen to crop out along the outer shelf plain or upper continental slope. The extent of the downcutting suggests pre-Pleistocene canyon initiation, although downcutting probably continued during the Pleistocene. At Bermagui Canyon, cutting continued after the onset of the Holocene transgression.

INTRODUCTION

Submarine canyons have been described from many parts of the world. Their possible origin and age of formation have been controversial since their recognition as long ago as 1893. Three main ideas persist to the present time: (a) canyons are the erosional products of turbidity currents of the types described by Daly (1936), and Keunen (1950); (b) canyons are mainly the result of subaerial erosion, the channels being kept open since submergence by sand flows and turbidity currents (Shepard, 1948); and (c) canyons are produced by the erosive power released by mass movement and slumping on unstable slopes (Stetson, 1949; Shepard & Dill, 1966).

Many workers have placed the age of formation of submarine canyons in the Pleistocene, and attributed their origin to fluvial downcutting during low sea levels. However, Menard (1960) and Menard et al. (1965) have shown that a pre-Pleistocene origin is likely for many canyons, owing to the large volumes of terrigeneous sediment contained in abyssal fans at canyon mouths. Von der Borch (1968, 1972) described submarine canyons off South Australia and eastern New Guinea, which he believes were initiated in the early Tertiary. Conolly (1968) identified and described large canyon systems in Bass Strait, and stated that their downcutting occurred primarily in the Pliocene. Phipps (1963) discovered and briefly described two submarine canyons on the east coast of New South Wales, at Jervis Bay and Ulladulla, which he considered were of Pleistocene age.

The features described below were charted during a marine geological reconnaissance of the New South Wales shelf by the Bureau of Mineral Resources (BMR) in 1972, during which echo-sounding and seismic profiles were obtained (Davies & Marshall, 1972). Ten possible submarine canyons were identified between Jervis Bay (latitude 35°S) and Bermagui (latitude 36°30'S). Their positions and the bathymetry of the continental shelf are shown in Figures 1 and 2. The isobaths are drawn from soundings on Australian Charts 806 and 807 (1:150 000). Deep-water bathymetry (Fig. 3) is taken from the G.E.B.C.O. 1:1 000 000 Oceanic Soundings Sheet No. 443.

DISTRIBUTION AND DESCRIPTION OF THE CANYONS

Canyons east and southeast of Jervis Bay

Three possible canyons crossed in this area are named informally Beecroft Canyon, Perpendicular Canyon, and St George Canyon, from prominent shoreline features. Their positions are shown in Figure 1, and echo-sounder profiles across them are shown in Figures 4 and 5.

The head of Beecroft Canyon was crossed at latitude 35°07'S. Two profiles are shown in Figures 4 and 5. In Figure 4, the canyon is V-shaped, and the tops of the canyon walls are at depths of between 373 and 404 m. The canyon is only 0.5 - 1.0 km wide. The bottom was not recorded, but is more than 300 m below the top of the walls. The sides of the canyon are smooth, and the shoulders have varied relief, presumably owing to erosion associated with widening of the shoulders of the canyon. Figure 5 is a profile across the Beecroft Canyon in slightly deeper water. It shows that the canyon has increased in width to 15 km, and consists of a wide upper portion, and a V-shaped lower portion from 530-728 m. The two parts are separated by a broad gently inclined terrace on the north side, and a much narrower terrace on the south side, at depths of about 500 m. A terrace or step occurs at 410 m on the south side. The echo profile shows that the canyon has a relatively smooth surface.

Perpendicular Canyon was crossed at latitude 35°12'S, longitude 100°59'E. The profile across it is shown in Figure 4. Perpendicular Canyon is morphologically similar to Beecroft Canyon. It is typically V-shaped, and has shoulders at 379 m and 366 m. Its bottom, which is flat-floored, is at 596 m. Some irregular relief is present on the northern shoulder. The canyon is 1.0 km wide across the shoulders, and 0.25 km wide across the floor. It is possible that Beecroft and Perpendicular Canyons form one system and coalesce farther east. This is the likely reason for the marked widening of the Beecroft Canyon shown in Figure 5.

The St George Canyon occurs at latitude 35°17'S. It is much smaller than the Beecroft and Perpendicular Canyons, is 1.0 km wide, and has its southern shoulder at a depth of 370 m and its floor at 448 m. The V-shaped cross-section is absent and the feature is probably a canyon head.

Conjola Canyons A and B

Two canyon-like features were crossed to the east of Lake Conjola (Fig. 1). Phipps (1963) has described a canyon to the east of Ulladulla but it is not known if his Ulladulla Canyon is the same as either of the features described here.

Although both features are called canyons, Conjola A does not have the typical canyon section (Fig. 6). However, both are figured because they occur in close proximity in an otherwise undissected continental slope. The shoulders of both canyons are at a depth of about 415 m. The floor of

Conjola A is at a depth of 476 m, and that of Conjola B at 512 m. Conjola A is about 2.0 km wide, and Conjola B is only 0.5 km wide. Both Conjola A and B are cut into the prograding sediments which form the continental slope (Fig. 6).

Batemans Bay Canyon System

The echo profile across the Batemans Bay canyon is shown in Figure 7. Both east-west parts of the profile show a very sharp shelf break at about 140 m. On the north side of the canyon the shelf break is followed by a steep descent down to at least 385 m. The canyon shoulder on the north side is at 440 m, and on the south side it is at 545 m. The canyon is 8.0 km wide and its floor is at a depth of 640 m. The deepest part of the canyon is beneath the southern wall. The floor to the north forms a chaotic jumble which is probably the result of mass movement of sediments down the northern slope. The canyon walls, however, are relatively smooth. They are not stepped in the manner described by Phipps (1963). Although the north-south profile shows an atypical canyon shape, the probability that the feature forms part of a large canyon system is supported by the continental slope bathymetry which shows a canyon system extending down to 4500 m.

The Moruya and Tuross Canyons

Three canyon-like features were crossed during seismic profile 21 (Fig. 1). East-west profiles to the north and south of the canyons and a north-south section across the canyons are shown in Figure 8. The depths to the canyon floors are 640 m (Moruya Canyon), 585 m (Tuross A), and 695 m (Tuross B). Tuross B with the typical V-shaped cross-section is probably a true canyon, the other two are probably the heads of small tributary canyons. It is likely that all three merge to form a significant feature to the east. Tuross B Canyon is about 3.0 km in width. The profile (Fig. 8) shows a gentle, stepped southern slope; steps occur at 530, 570, and 636 m. The northern slope is steeper, and has steps at 530, 570, and 599 m. The lower part of the canyon forms a deeply incised V. It appears that the steps can be approximately correlated from canyon to canyon, suggesting that they form part of the same system and have been subject to similar conditions of formation. The seismic sections show that the surface is smooth, and that the canyons are cut into the prograding shelf-edge sequence, and not into basement as has been suggested by Phipps (1963). This is comparable to the situation described for the Conjola system.

Bermagui Canyon

The position of the Bermagui Canyon is shown in Figure 2 and a seismic section across the canyon in Figure 9. The canyon is 6.0 km wide between shoulders whose depths are both 472 m. It is symmetrical, with a flat floor 1.0 km wide at a depth of 695 m. Steps occur on the south side at 629 m, and on the north side at 644, 549, and 490 m. The canyon is cut into the prograding sediments forming the continental slope. Nowhere is it seen to be cut into basement. An important feature of this canyon is that it heads above 120 m, i.e. above the shelf break, which in this area is at a depth of 140 m.

CANYON DISTRIBUTION WITH RESPECT TO SHELF BATHYMETRY, AND SHELF STRUCTURE

The bathymetry of the continental shelf, and the onshore drainage pattern south of latitude 35°S are shown in Figures 1 and 2. Isobaths are drawn at 10-m intervals. The bathymetry of the slope and abyssal plain south of latitude 35°30' is shown in Figure 3. The deep-water data are taken from the 1:1 000 000 Oceanic Sounding Sheets of the G.E.B.C.O. series compiled by the Hydrographic Office (corrected to December, 1971). Differences in detail exist between this and that published by Conolly (1968). Sufficient data for reliable contouring north of latitude 35°30'S are not available. The following conclusions are tentatively drawn from the data shown in Figures 1, 2, and 3.

(a) The configuration of the bathymetric contours (Figs. 1 and 2) delineate possible courses of submarine river systems, but seismic profiles across this area do not indicate visible depressions. The possible river courses may therefore be artifacts of the sounding data.

(b) The ocean soundings chart (Fig. 3) shows that large canyon systems, extending down to 4500 m, occur southeast of Batemans Bay and southeast of Bermagui. This correlates therefore with echo and sparker profiles. Figure 3 also indicates the presence of a large canyon east of Two Fold Bay. Echo and seismic profiles at a depth of 300 m across this area did not reveal the presence of a canyon and presumably this canyon heads below this depth.

(c) Figure 2 also indicates marked inflections of the bathymetric contours to the west of the Bermagui Canyon, suggesting an extension of the canyon across the continental shelf as far as the 120-m isobath. This is 30 m above the shelf break which in this area is at 150 m, suggesting that canyon-cutting has continued after the formation of the shelf break. The 1972 BMR cruise showed that canyons did not occur between Jervis Bay and Port Stephens, but formed only in the area south of Jervis Bay. The question should be raised therefore as to why this is the case.

Phipps (1963) considered that the shelf edge to the south of latitude 35°S is largely composed of Palaeozoic rocks which crop out on the upper slope and that the canyons cut into the Wagonga Series (Phipps, 1963, pp. 40, 44). He further considered that south of latitude 35°S, the continental margin retreated westwards, 'All sediments accumulating on this slope are being washed by turbidity currents into the oceanic plain', while to the north of Jervis Bay 'the smooth surface of the slope indicates that this part of the shelf is being built up'. Phipps also suggested that the coincidence of slope sediment accumulation with the outcrop of the Permian-Triassic sediments of the Sydney Basin may be significant.

Three sections depicting the shallow seismic structure of the continental shelf in the area, are given in Figure 10. Figure 10A is typical of the shelf in the area north of Jervis Bay, Figure 10B shows the section east of Jervis Bay, and Figure 10C that of the shelf east of Eden. Table 1 summarizes the characteristics of the structure, morphology, and sediments in the three areas. The following tentative conclusions are drawn from Figure 10A, B, C, and Table 1.

(i) The inclination of the continental slope is greater to the south of Jervis Bay than to the north.

(ii) Prograding sediments at least 300 m thick form the continental slope to the north and south of Jervis Bay. In the extreme south of the area, the sediment thickness exceeds 600 m. Basement rocks do not crop out on the upper continental slope anywhere in the area traversed.

(iii) To the north of Jervis Bay, a disconformity is visible within the sedimentary sequence (S1 in Fig. 10). This has not been identified in the area to the south of Jervis Bay. However, three disconformities can be identified in the southern region.

(iv) Truncation of sediments against the continental slope is the rule in the area to the south of Jervis Bay but occurs less commonly in the northern area.

(v) The present shape of the continental edge is largely related to the basement structure. Seismic basement progressively steepens, deepens, and more closely approaches the present coastline to the southwest. The thickest sedimentary sequence therefore lies in this direction. This simple southerly increase in thickness of sediments overlying basement is somewhat complicated by the basin-like shape of the Permian-Triassic subsurface.

From the above it is concluded that two major features differentiate the areas north and south of latitude 35°S: (a) the dip of the present continental slope which is a function of the basement inclination, and (b) the unconformable surface S1 which occurs to the north of Jervis Bay while to the south three disconformities can commonly be recognized. The erosion of submarine canyons may be related to the formation of the three disconformities in the southern area.

AGE OF THE CANYONS

Phipps (1963) postulated a Pleistocene age for the initial formation of the canyons to the east of Jervis Bay and Ulladulla. The present work has produced little evidence bearing on their age of formation.

The Batemans, Bermagui, and Two Fold Bay canyon systems extend to a depth of 4500 m. Conolly (1960) reported coalescing sediment fans at the base of the continental rise south of Jervis Bay. It seems unlikely that erosion attributed wholly to the Pleistocene sea level fluctuations could be sufficient to form such large features to depths of 4500 m.

Three disconformities have been detected in the seismic sections in the area south of Jervis Bay. Their time relations with S1 (Fig. 10) in the area north of Jervis Bay are unknown. However, it is apparent that massive erosion, slumping, and the formation of new slopes has occurred several times in the past. These are likely to be pre-Pleistocene.

The Bermagui Canyon appears to cross the shelf and head at 120 m. This is 20-30 m above the depth of the present shelf break, suggesting that cutting of this canyon continued after the Holocene transgression began.

On balance the evidence is thought to indicate a pre-Pleistocene age for the start of canyon formation although extensive downcutting occurred during the Pleistocene, and in the case of Bermagui Canyon continued after the Holocene transgression began.

CONCLUSIONS

1. Submarine canyons or associated features were crossed along the continental edge of southeast Australia south of Jervis Bay. Latitude 35°S during the 1972 BMR cruise.

2. The canyons range in width from 0.5 to 1.5 km, and in depth from 448 to 728 m. Many appear to be asymmetrical with the deepest part occurring beneath the northern face, but this may be due to the crossing angles. The sides of the canyons are smooth or stepped. Steps on the Moruya and Tuross Canyon systems can be correlated, and extend down to 637 m depth.

3. The canyons have narrow flat floors except Bateman Bay Canyon whose southern side is composed of hummocky terrain, presumably the result of mass movement down the southern slope.

4. All canyons are cut into a prograding shelf sequence. There is no evidence of basement cropping out on the upper continental slope.

5. All the canyons appear to head below the present shelf break, except Bermagui Canyon which heads 20 m above the shelf break.

6. Ocean soundings corroborate the echo and sparker profile data. Large canyon systems extend to a depth of 4500 m to the southeast of Batemans Bay and Bermagui. The large canyon system to the southeast of Two Fold Bay heads below a depth of 300 m.

7. Where canyons are present to the south of Jervis Bay the continental slope is steeper than it is to the north. The steepness of slope is related to the steep dip of seismic basement.

8. The canyons east of Jervis Bay have been previously described as Pleistocene. It is likely, however, that downcutting began earlier.

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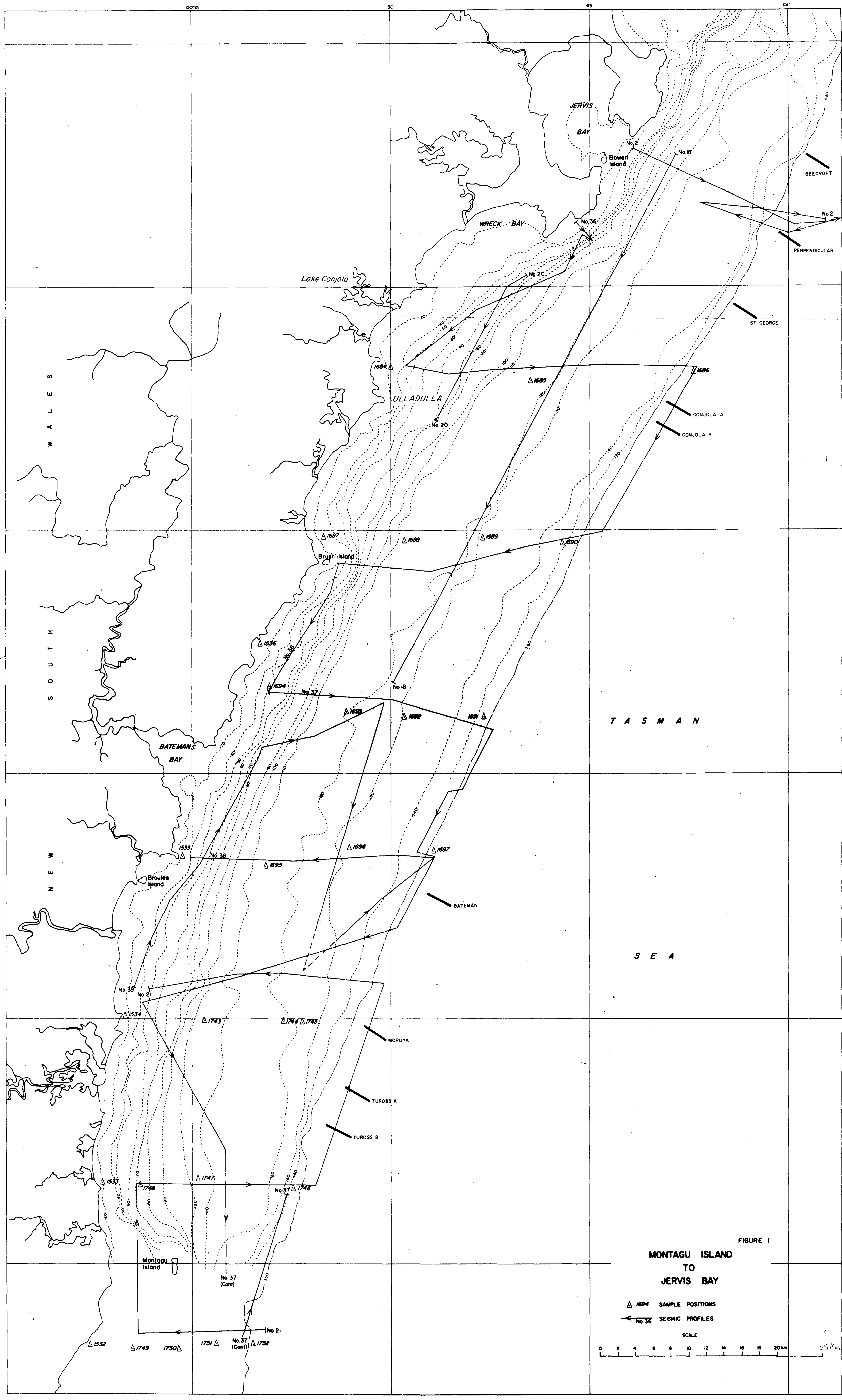
TABLE 1 - DATA FROM SECTIONS DEPICTING THE STRUCTURE OF THE CONTINENTAL SHELF

Section	Morphology	Sediments	Structure
A. Section east of Port Kembla - Wollongong. Latitude 33°30'	Shelf width = 50 km S.B. = 160 m Dip of cont. slope = 1°12' Type of slope = terraced and smooth	Prograding sequence, at least 300 m thick. Unconformity in sedimentary pile	Basement highs at depth of 100-120 m. Basement then dips gently east-wards. No basement outcrop on the upper continental slope. A disconformity can be seen in the shelf edge
B. Section east of Jervis Bay. Latitude 35°10'	Shelf width = 21 km S.B. = 168 m Dip of cont. slope = 4°24' Type of slope = terraced and canyoned	Prograding sequence, at least 300 m thick. Unconformity in sedimentary pile	Basement high at depth of 110 m. Basement then dips eastwards. No basement outcrops in the upper continental slope. A disconformity in the shelf edge sequence can be traced back across the shelf
C. Section east of Eden. Latitude 35°30'	Shelf width = 30 km S.B. = 120 m 120 m Dip of cont. slope = 1°-14° Type of slope = terraced	Prograding sequence = 600 m. No unconformity in sedimentary pile. Truncation of sediments on slope	No high occurs in the basement. Steep basement slope is also reflected in dips of sediments. The steep basement slope is also seen in sections farther south. No basement outcrops near continental edge



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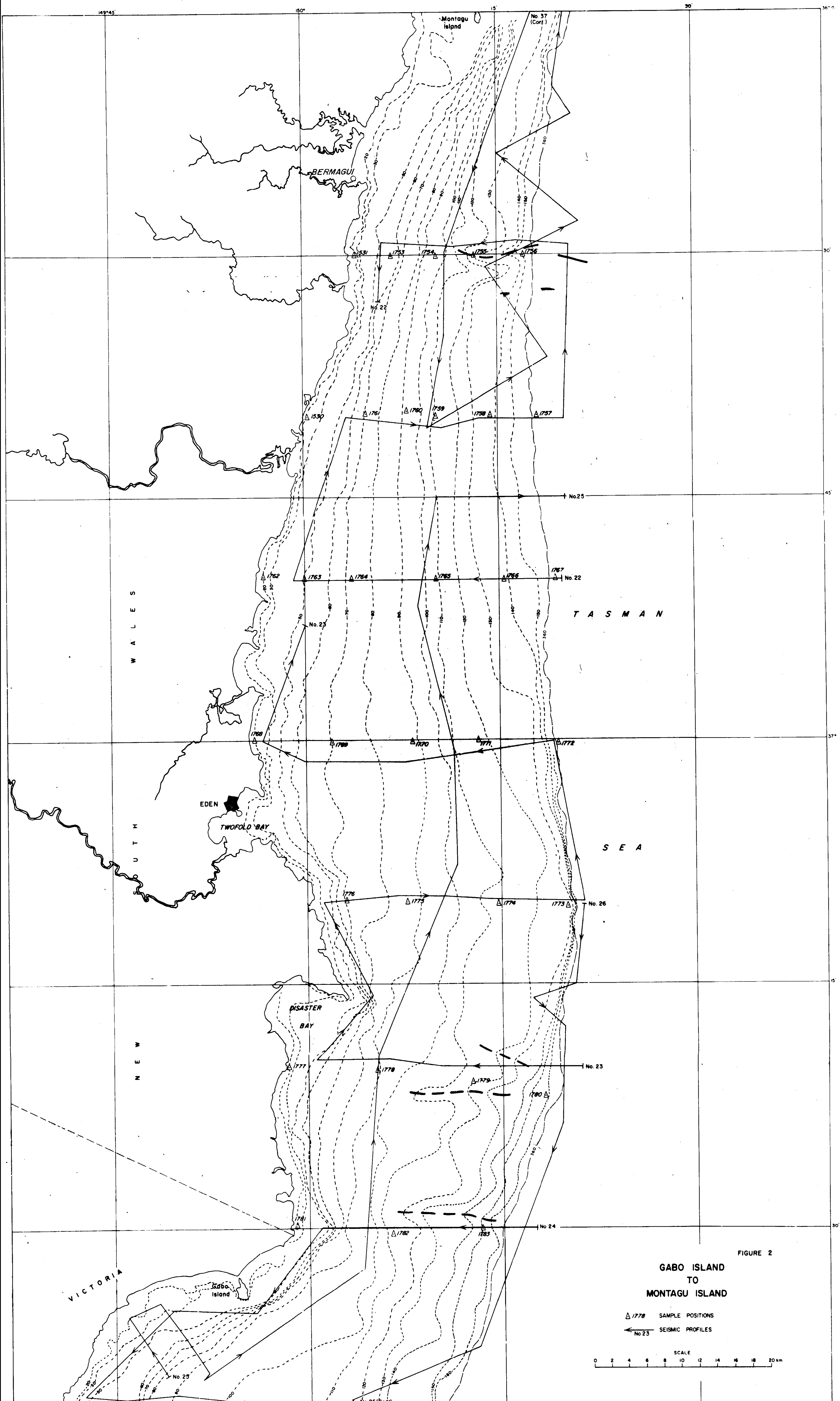

FIGURE 2

GABO ISLAND TO MONTAGU ISLAND

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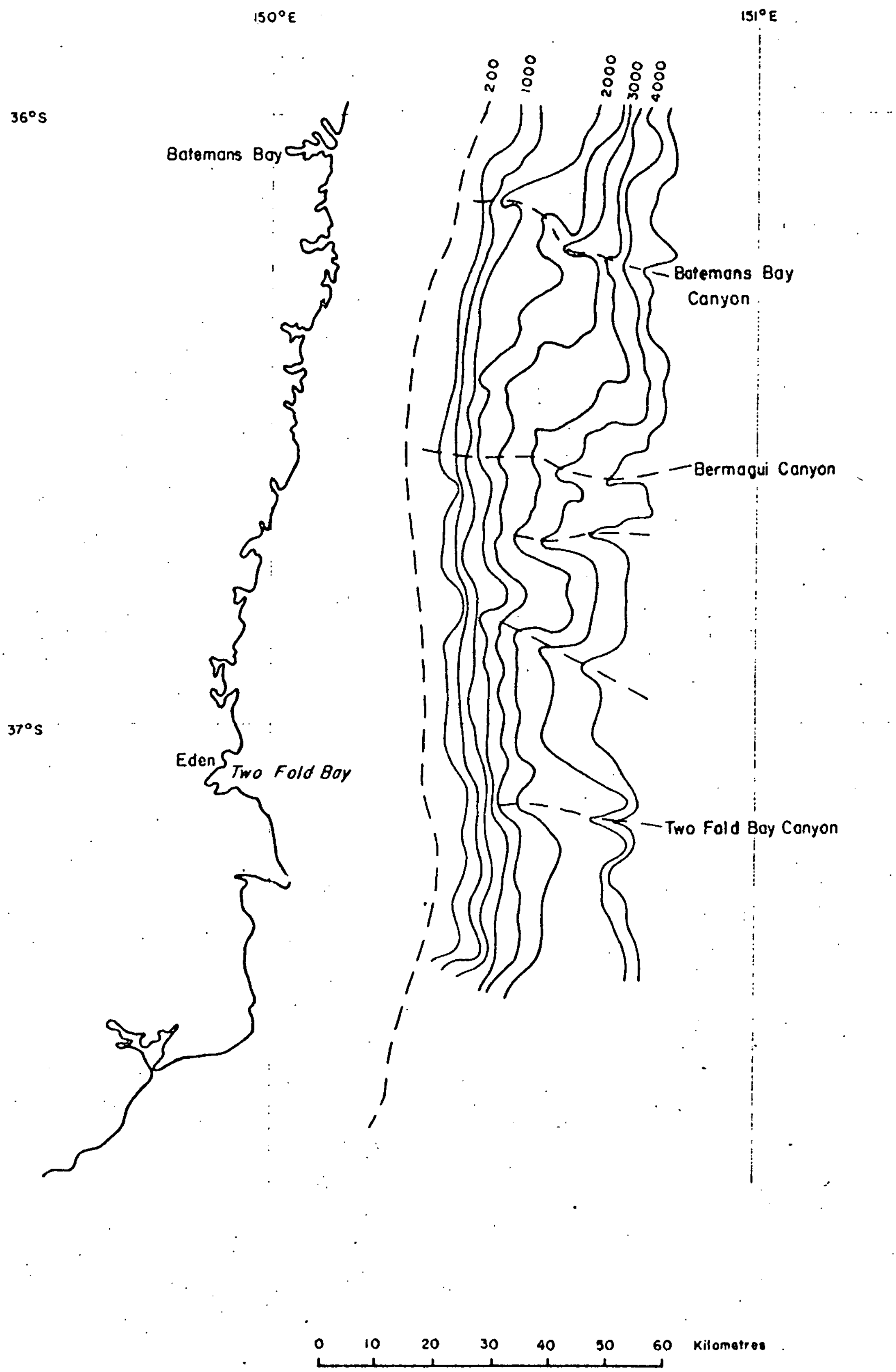
Fig. 3 Bathymetry of the outer continental margin south of Batemans Bay (metres)



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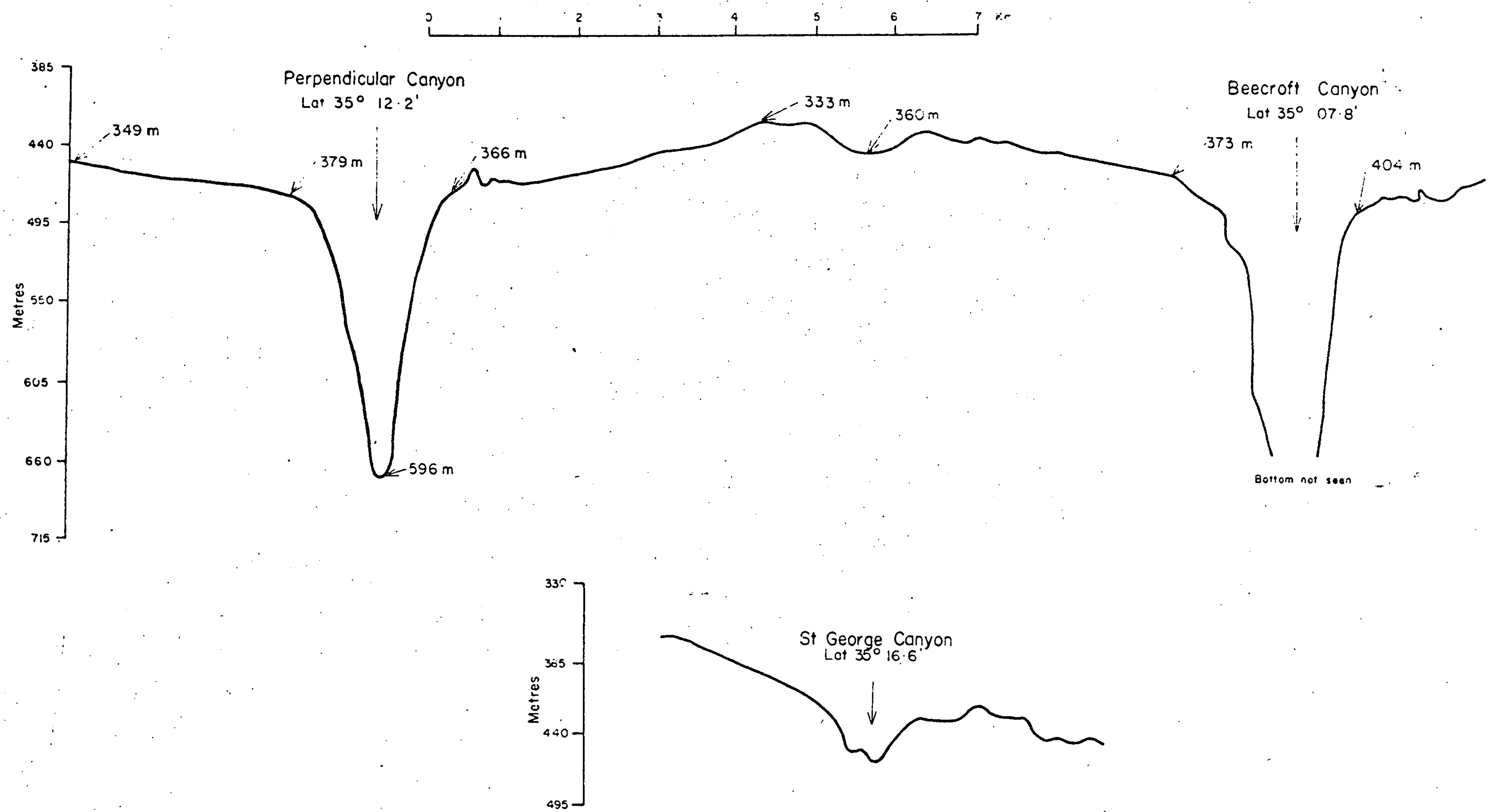

Fig. 4. Canyons east and east south of Jervis Bay.

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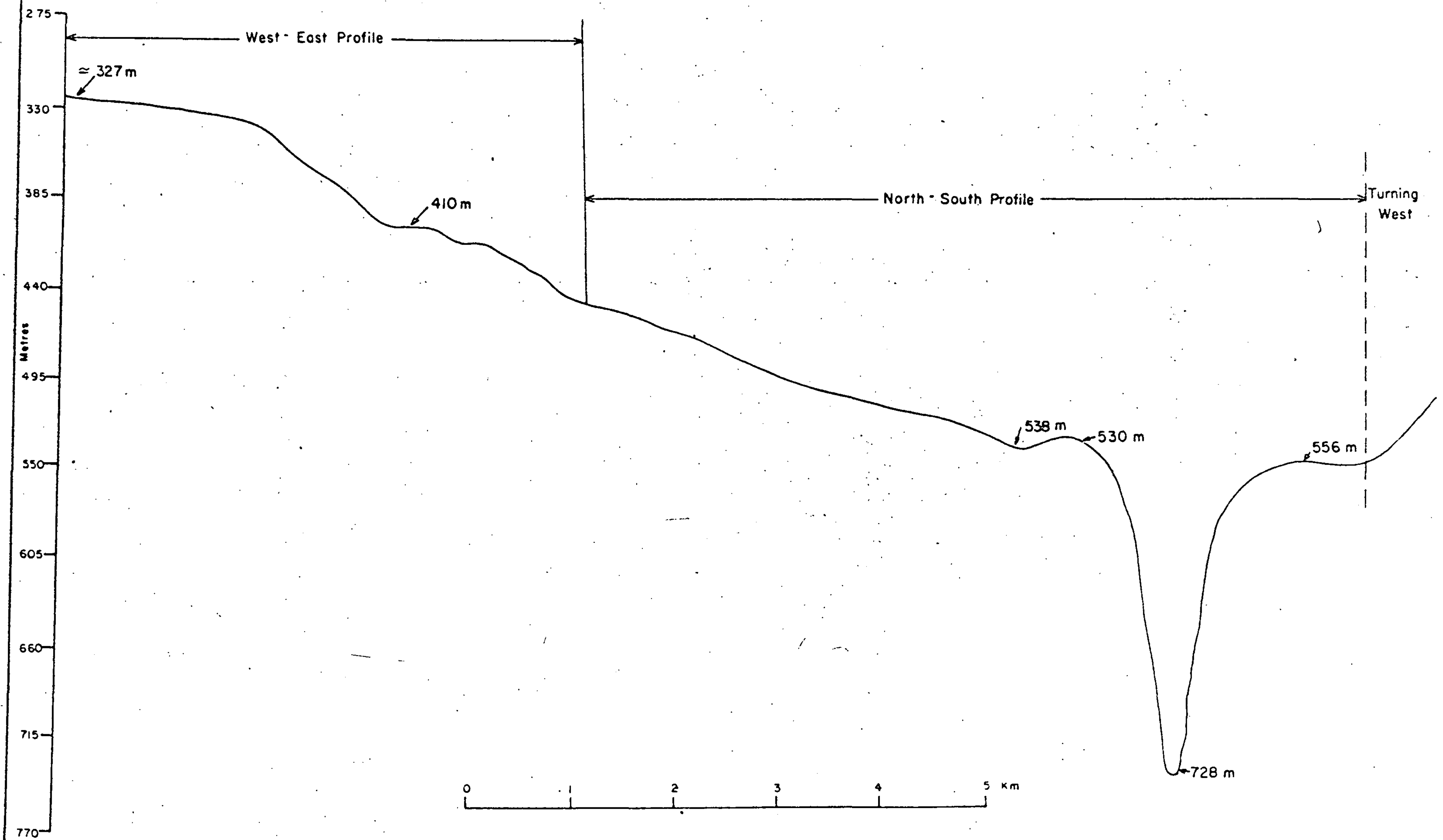
Fig. 5 Echo profile across Beecroft Canyon



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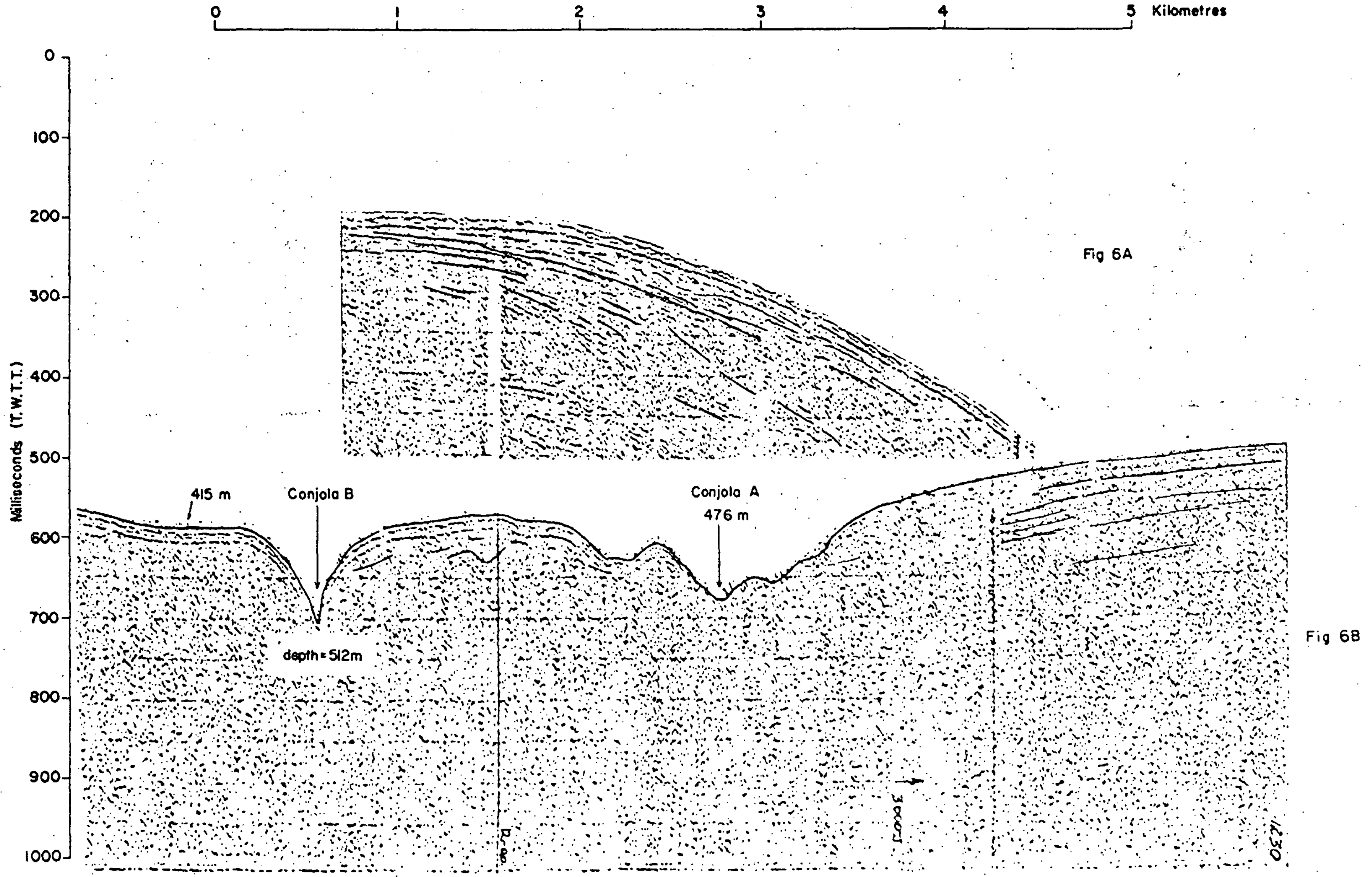

Fig. 6. Seismic profiles across the Conjola Canyons.

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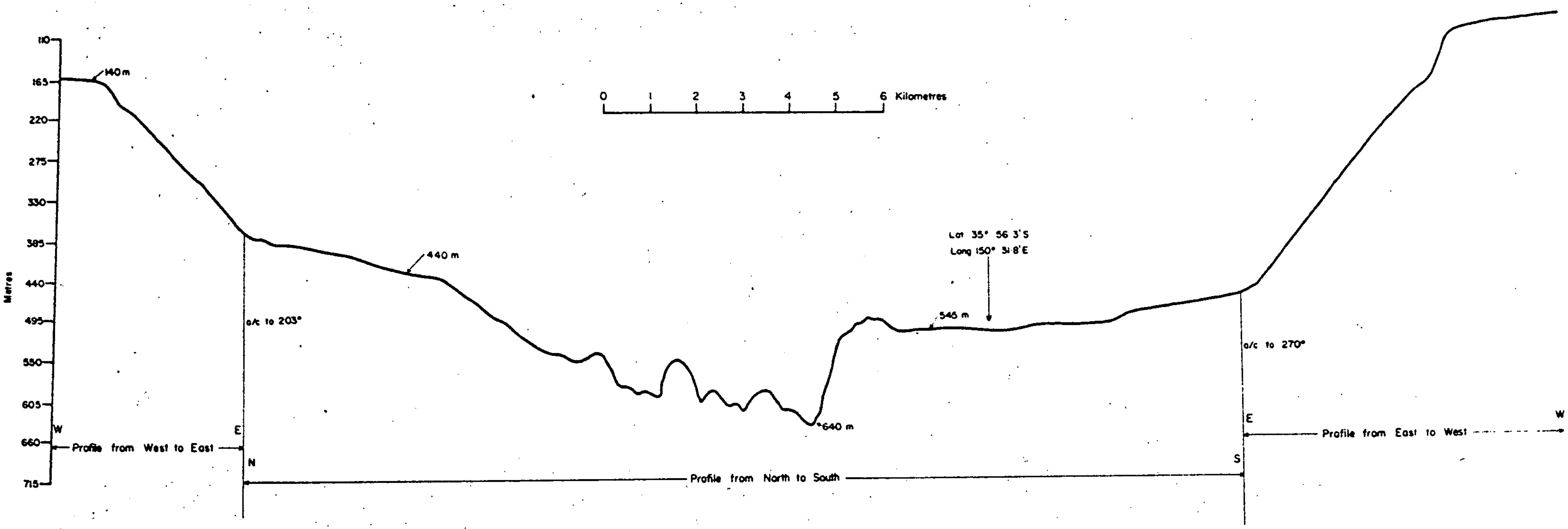

Fig 7 Echo profile across Batemans Bay Canyon.

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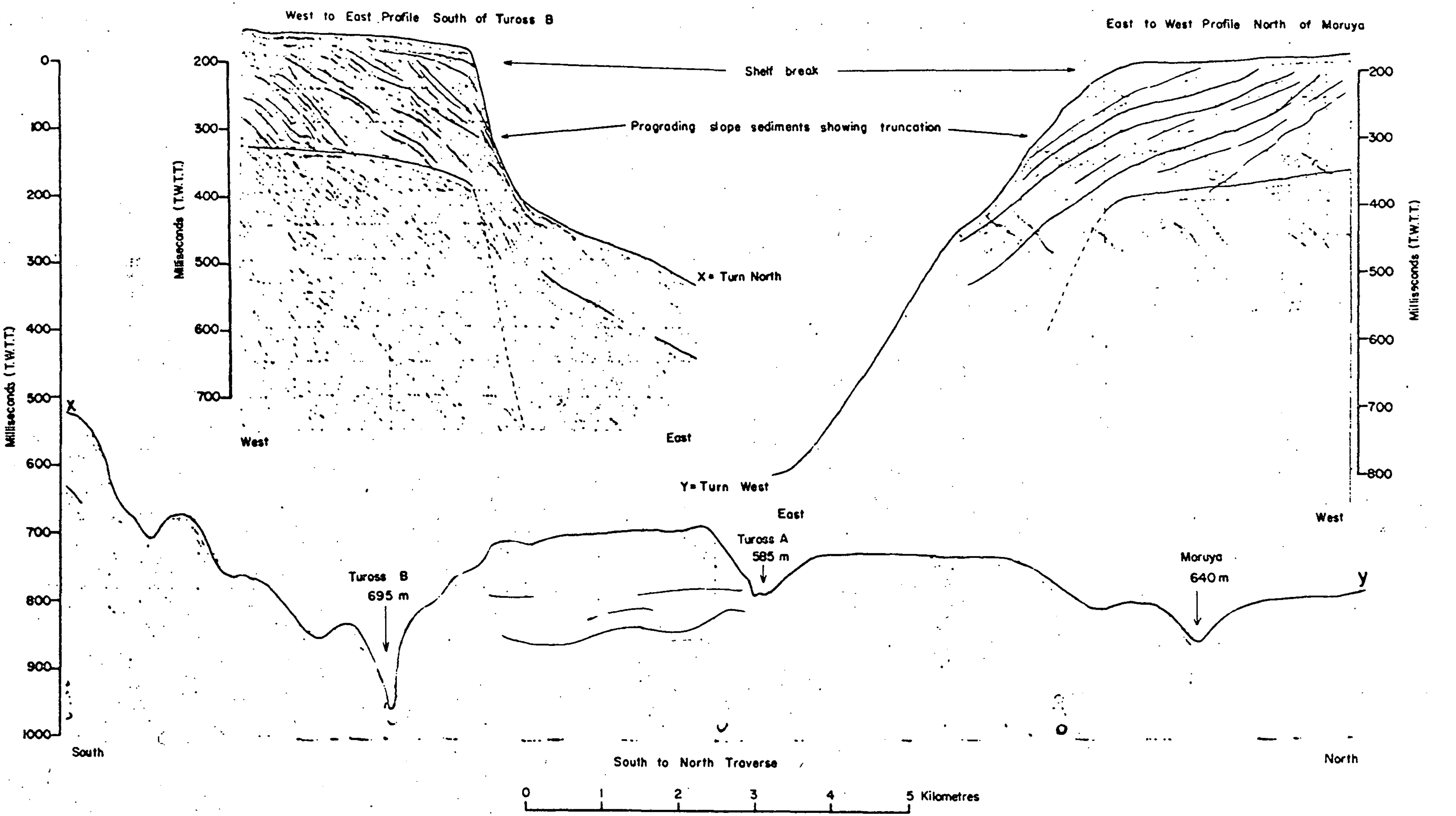

Fig. 8 Seismic profiles across the Tuross and Moruya Canyons and the continental slope north and south of the canyons

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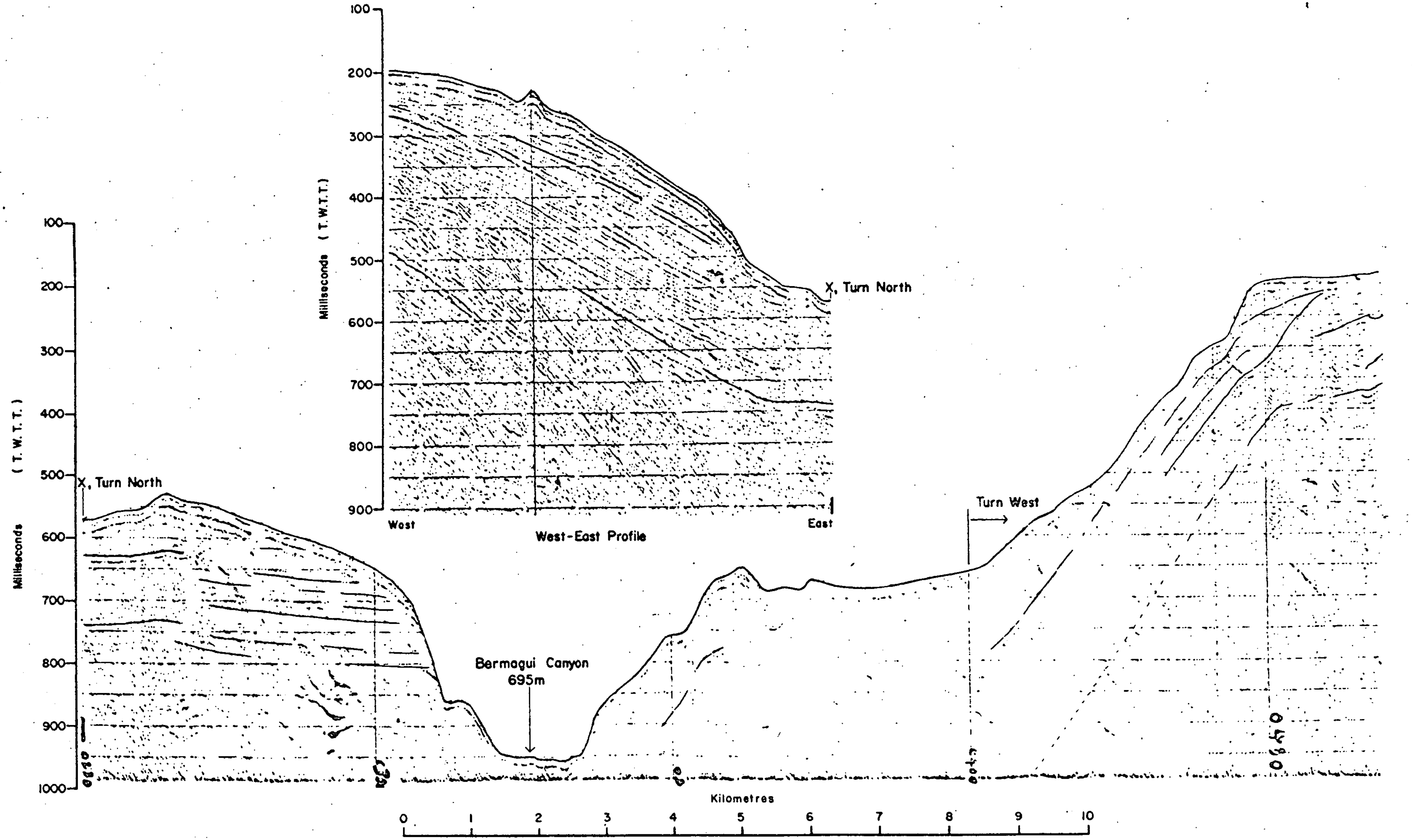

Fig. 9. Seismic profile across the Bermagui Canyon and the continental slope north and south

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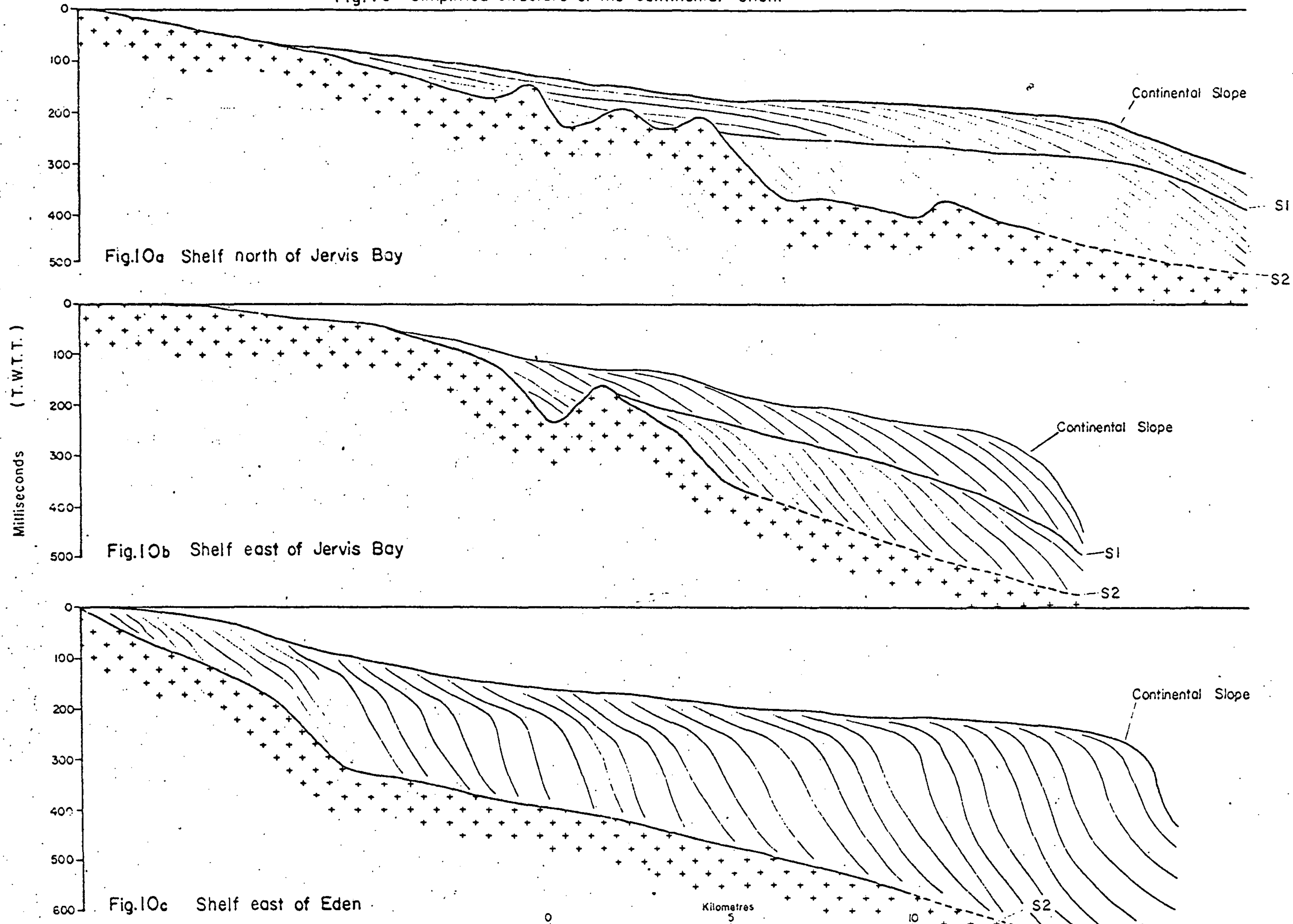
Fig. 10 Simplified structure of the continental shelf.



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