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MORPHOLOGY OF THE EAST AUSTRALIAN CONTINENTAL SHELF BETWEEN CAPE MORETON AND TWEED HEADS IN RELATION TO OFFSHORE HEAVY-MINERAL PROSPECTS

by

H.A. Jones

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SUMMARY

New bathymetric data acquired by the Division of National Mapping have been studied with the objective of delineating fossil beaches and other features which may be associated with concentrations of heavy minerals. Use has also been made of near-shore profiles obtained by the Gold Coast City Council and of the results of drilling by Planet Metals Ltd.

Submerged shorelines have been recognized at several levels above a depth of 184 m. The most widespread coincides with the shelf break at about 100 m. Channels representing drowned coastal swamps also occur on the shelf.

The beach dune system of the present-day coast stands at the crest of a slope which continues seawards for about 2 km before levelling off at a depth of 25 m. If a similar form was developed during earlier low sea-level still-stands, it follows that fossil beach dunes are likely to be found on the crests of slopes separating terraces on the continental shelf.

Offshore drilling by Planet Metals Ltd near the southern margin of the area was carried out close to the foot of the present-day paralic zone slope. On morphological grounds it would appear that the outer rather than the inner margins of continental shelf terraces hold out the best prospects for heavy-mineral concentrations.

INTRODUCTION

Accurately positioned and closely-spaced sounding lines across the continental shelf between the 20-m and 300-m isobaths recently obtained by the Division of National Mapping provide an important new source of data on the detailed physiography of the shelf. A study of the original echograms has been carried out with the objective of delineating features which may be related to submerged shorelines and other forms possibly associated with deposits of heavy minerals.

The bathymetric survey of the continental shelf being carried out by contractors for the Division of National Mapping started in Queensland waters in mid-1971. The first of the original echograms made available for study by BMR covered the continental shelf from Sandy Cape, Fraser Island, to Cape Moreton, off Brisbane, and a description of these profiles has recently appeared in the BMR open file Record series (Jones, 1973). The present paper is a continuation of this work and extends the coverage from Cape Moreton to Tweed Heads on the Queensland/New South Wales border, a distance of 126 km; part of the introductory section, and part of the section on heavy-mineral prospects are the same in both papers.

The area covered by the bathymetric survey is about 4930 km^2 and a total of some 3670 km of sounding profiles were obtained (Fig. 1). Throughout the area east-west sounding lines were spaced 1.5 km apart and a number of north-south and diagonal tie-lines were also run. The contractors used an Edo echosounder consisting of a model 578 recorder and a model 480 transducer. This instrument used a 38 kHz acoustic source with a peak power output of 150 W and a pulse length of 1 or 1.5 ms. The straight-line recorder had a sweep of 65 feet or 65 fathoms (20 m or 119 m) over a paper width of 15.5 cm. Scale was adjustable in four steps down to 280 fathoms (512 m). At the ship speeds and paper feed rate used during the survey, vertical exaggeration of the scale on the echograms is about x45 on the foot scale and x15 on the fathom scale. Use of the foot scale was restricted to the inshore end of the traverses in water depths of less than 35 m.

The quality of the echograms was usually good, although identification of small-scale irregularities of the sea bed was sometimes made difficult by undulations of the trace caused by sea state. The contractors were required to carry out bar checks twice daily, and to maintain sounding accuracy within 1 percent. Depths were corrected to Mean Sea Level, the normal topographic map datum, rather than to the datum used on Australian and British Admiralty charts, which is close to Low Water Springs; in the context of this work, the difference between the two is not significant.

Positioning was carried out by Raydist, a medium-range radio system in which the phases of two continuous-wave signals are compared. Under the terms of the contract, positioning accuracy was required to average 100 m, seldom to exceed 200 m, and never to exceed 300 m. Data compiled by the Instrument Division of the U.S. Coast and Geodetic Survey indicate that the Raydist system achieves a much higher order of accuracy than this, and there is no evidence to suggest that positioning errors exceeded those specified.

REGIONAL MORPHOLOGY

The continental shelf, measured from the shoreline to the shelf break at about 100 m depth, ranges in width from only 8.5 km off Cape Moreton to 33.7 km at its widest point off Southport. In relation to the mainland, however, there is a regional broadening of the continental shelf northwards; ignoring Moreton Island and North and South Stradbroke Islands, and including Moreton Bay with the continental shelf, it ranges from a minimum of 23 km off Tweed Heads to a maximum of about 50 km at Moreton Island.

The generalized east-west profiles off Moreton Island and North Stradbroke Island (Fig. 2) illustrate the main morphological elements of the region. As is the case to the north of Cape Moreton, the top of the true continental slope commonly lies beyond the limit of the survey at depths exceeding 300 m. It can, however, be identified in most profiles in the northern part of the area from Cape Moreton to about 27°24'S at depths of 280 to 320 m. South of this latitude it is crossed in only a few traverses (e.g. southern profile, Fig. 2), and generally a very gentle, more or less constant gradient is maintained from the shelf break to the outer margin of the area surveyed (Fig. 2, northern profile).

The shelf break is defined as the point where an increase in gradient at the outer edge of the continental shelf marks the start of the continental slope. Throughout this area it is taken to be at about 100 m, for although the continental slope proper begins at a much greater depth, the inflection near the 100-m bathymetric contour is sufficiently marked to delimit the shelf clearly (Fig. 2). Thus, as is also the case in the adjoining area to the north, a zone of gently inclined sea floor separates the true continental shelf from the true continental slope. This zone does not readily fit into any of the commonly used morphological subdivisions of the continental margin; it may be regarded as a rather shallow, poorly defined marginal plateau similar to the Scott Reef/Rowley Shoals Platform of the Northwest Shelf, or as the gently inclined uppermost part of the continental slope.

The gradient across this intermediate zone averages about 0.5° and usually shows little variation in individual profiles; however, for a distance of about 30 km south of 27°30'S a narrow, ill defined terrace occurs at about 240 m depth. Even where there is no change of slope, as in the northern profile, Figure 2, an undulating surface, commonly characterized by strong sound reflection, occurs at this depth. This terrace or undulating surface marks the outcrop of Tertiary sediments, possibly an erosional surface, which is identifiable in most seismic reflection profiles in this area and farther north (Jones, 1973). This intermediate zone also includes a change of slope at a depth of 175 m, which represents a submerged shoreline; this is described later.

The main morphological features of the shelf itself, from the shelf break at about 100 m to the inner limit of bathymetric data at 20 m, are illustrated by the regional profiles (Fig. 2). The edge of the shelf close to the shelf break almost always has an irregular surface and commonly forms a low bank. The outer shelf is nearly everywhere occupied by a terrace at a depth of about 85 m and other less widespread terraces occur at shallower depths. A marked steepening of slope usually occurs close to the inshore end of the area surveyed at depths of 20 to 30 m.

DETAILED MORPHOLOGY OF THE SHELF

The submerged shorelines, banks, and channels on the shelf identified in the bathymetric profiles are shown in Plate 1, and tracings of portions of individual echograms to illustrate particular features appear in Figure 3.

Banks and uneven ground

The outer edge of the shelf close to the shelf break is almost invariably uneven and contrasts sharply with the smooth depositional slope seawards and the flat terrace of the outer shelf landwards (Fig. 3,B). It is also commonly slightly elevated and forms a low irregular bank rising a few metres above the level of the outer shelf terrace (Fig. 3,E). The width of this bank of belt of uneven ground ranges from a few hundred metres to about 3 km, but its margins are in places not well defined. Where a bank is present it is generally only 3 to 5 m above the level of the terrace on the landward side; the maximum relief recorded was 13 m near the northern margin of the area at 27°6.1'S.

Other linear banks and zones of uneven ground are present on the middle and inner shelf. These too are roughly aligned with the shelf edge and commonly occur on the outer edge of terraces (Fig. 3,C). None forms a semi-continuous feature like the bank near the shelf break, and the longest single bank measures 11 km. No sand waves were detected in the profiles.

Channels

Channels are present on the shelf and, as is the case to the north of Cape Moreton, they run parallel to the coastline and bear no relation to the drainage pattern onshore. All are very subdued features, and although individual channels can be traced for long distances, they are seldom more than 4 or 5 m deep. They represent a drowned system of coastal swamps and lagoons similar to that behind the present-day beaches. The most prominent runs along the outer shelf terrace with few breaks for a distance of 75 km from 27°20'S to 28°12'S. It appears as a shallow saucer-shaped depression in the central part of the southern profile, Figure 2.

No submarine canyons dissect the shelf in the area, although in the absence of any north-south tie-lines seaward of the 200-m bathymetric contour, it is possible that some may be present near the outer margin of the area surveyed beyond the shelf edge.

Submerged shorelines

Terracing of the shelf is everywhere evident, but the zones of increased gradient between terraces are in places wide and poorly defined (Fig. 2). The most widespread terrace occupies the outer shelf at a depth of about 90 m everywhere except off the southern part of Moreton Island. An extensive terrace also occupies the middle shelf at depths of about 55 m south of 27°30'S, and smaller, less well defined terraces occur in both shallower and deeper water throughout the region.

The linear zones of relatively steep gradient which separate the terraces are aligned roughly parallel to the coast. There is a high probability that these features are associated with drowned shorelines formed during periods of static sea level, which occurred in the transgressive and regressive cycles of the Quaternary. Most were probably developed during the last (Holocene) transgression, as it seems unlikely that such features in unconsolidated shelf sediments would escape obliteration by erosion and sedimentation if formed earlier. As it is, their surface expression on the present-day sea floor is usually very subdued, and the gradients are extremely low.

The distribution of the changes of slope identified from the bathymetric profiles is shown in Plate 1. The deepest ranges in depth from 168 to 184 m and extends for a distance of 45 km from 27°12.5' to 27°36.5'S. A change in slope at this depth is locally present on the upper continental slope between Fraser Island and Cape Moreton and has been described in some detail, and identified as a shoreline feature, in the Capricorn Group at the southern end of the Great Barrier Reef by Veeh & Veevers (1970). Off Moreton and North Stradbroke Islands it takes the form of a slight, generally gradual decrease in gradient on the gently inclined upper continental slope 5 to 8 km seaward of the shelf break.

The most widespread, best developed submerged shoreline is at about 100 m depth and is coincident with, or just below, the shelf break (Fig. 2; Fig. 3,B & E). It is recognizable in every east-west bathymetric profile, although in some places it is not sharply defined and it commonly splits into two or even three separate notches (Fig. 3,B). The extreme range of depths to the base of the changes of slope is 91 to 113 m, but there is no evidence of regional variations which might be attributable to warping of the continental margin.

Much of the outer part of the shelf is occupied by a terrace bounded on the landward side by a slope whose foot stands at a depth of about 85 m. The 85-m change of slope can be traced with few short breaks for a distance of 58 km in the central part of the area, and also occurs over short distances off the northern part of Moreton Island and off Tweed Heads. Tracings of two echograms crossing this feature are shown in Figure 3 (A & C), and it is also well displayed in the regional profiles (Fig. 2).

Several terraces are present in the shallower waters of the middle and inner shelf; however, except for a terrace at about 55 m which stretches for 36 km off North and South Stradbroke Islands, all are of very limited extent. The changes of slope close to the inshore end of the traverses are less persistent and less well developed than off Fraser Island and south of Double Island Point to the north of Cape Moreton. A marked increase in gradient commonly occurs at depths of between 33 and 19 m (Fig. 3,D & F), but individual features within a narrow depth range are not traceable for long distances.

OFFSHORE HEAVY-MINERAL DEPOSITS

This region borders the northern part of the east coast mineral-sands province and it is possible that deposits similar to those onshore are associated with submerged fossil beaches on the continental shelf. The pioneering offshore exploration work of Planet Metals Ltd during the late 1960s was designed to test this possibility, but did not extend north of Burleigh Heads (28°06'S) nor farther offshore than about the 35-m bathymetric contour. This company has reported that over 375 million tons of sand averaging 0.20 to 0.22 percent rutile plus zircon have been outlined by drilling off the central coast and a further 500 million tons indicated (Brown, 1971). Full descriptions have not been published, but there are apparently two types of deposit: a blanket type of unknown extent in which heavy minerals are present in the top 1.5 to 4.5 m overlying barren sand; and a seam type 3 to 4.5 m thick, 120 to 490 m wide, and up to 4.9 km long, which underlies 3 to 4.5 m of generally barren sand. Both types of deposit lie in water depths of about 30 m; it is assumed that they are associated with a fossil beach, but the company has not revealed whether this feature has any surface expression on the sea floor.

Reworking of fossil beaches

It is not known how and to what extent any heavy-mineral deposits which may have been associated with beaches now submerged would have been modified during and after the transgression of the sea. It is logical to assume that rising sea level and advance of the shoreline would result in partial destruction of the beach dune system and in some redistribution and dilution of heavy-mineral seams. It is also probable that the bulk of the littoral zone sand, the active paralic sand wedge of Dietz (1963), would migrate landwards with the advancing shoreline, except where the beach dunes are backed by lagoons or swamps. If this is so, then the present-day beach zone is likely to contain a major part of the total east coast heavy-mineral resources, even if large deposits were at one time concentrated in low-level shorelines on the continental shelf.

There is, however, a possibility that substantial deposits exist offshore, and although drilling has not yet revealed any high-grade deposits, these may also be present. While some reworking of the upper part of the beach profile appears inevitable during a transgressive phase, heavy-mineral seams lower in the profile could well be protected by the overburden, particularly if the rise in sea level was rapid. The chances of preservation would also be increased where some induration of the heavy-mineral sand body, or of the overburden, had occurred; this is not uncommon among the lower-level deposits onshore.

Location of fossil beaches and associated mineral concentrations

The base of the change of slope is usually readily identifiable in the profiles (see the indicated points in Figure 2). Although the actual shoreline during the still-stand was probably at a slightly higher level, these points have been used to plot the submerged shoreline distribution shown in Plate 1. Assuming that these features are in fact related to ancient shorelines, and that part of their associated beach deposits have been preserved, the question of the probable location of the deposits with respect to the change of slope remains. By analogy with the present coastline it would appear that the slope above the change, and particularly the crest of the slope, is the most likely area. Detailed soundings are generally not available inside the 20-m bathymetric contour, but the relatively steep gradient at the inshore end of almost all profiles appears to continue to the shoreline. This is confirmed by detailed surveys carried out by the Gold Coast City Council in connexion with their recent beach replenishment investigation between Tweed Heads and Southport. Several profiles recorded by the Council in this area show that the relatively steep gradient of the beach at mean sea level continues seawards until it starts to level off at about 25 m depth.

Thus in the present-day near-shore profile the known high-grade concentrations of heavy minerals occur within the beach dune system standing at the crest of a slope which continues seawards for about 2 km before flattening out some 25 m below sea level. If a further rise in sea level were to occur there would be a rapid transgression across the coastal lowland belt, once the beach dune system had been breached; profiles across the drowned area would show a flat or concave terrace bounded seawards by a bank or hummocky zone, marking the remnants of the beach dune system, standing at the crest of a slope representing the present near-shore gradient. Such a combination of features is recognizable in some of the profiles across the existing continental shelf. Clearly the most prospective area for concentrations of heavy minerals would lie on top of the slope, although local concentrations could also, be expected lower down, if this zone is indeed a fossil paralic sand wedge.

It has been noted above that offshore drilling has been carried out by Planet Metals Ltd in the southern margin of this region. In 1969, 42 holes were drilled between 1.7 and 4.4 km offshore in water depths ranging from 21 to 38 m in the area between Tweed Heads and Southport. Planet Metals Ltd have kindly supplied BMR with samples from their offshore drilling program, including those from the holes mentioned, and a study of this material is now being undertaken by the Sedimentology Group under Dr A.R. Jensen. Preliminary results indicate some interesting possibilities for stratigraphic correlation between holes, but the distribution of zones of relative enrichment in heavy minerals appears, at this stage, to be irregular.

On the basis of surface morphology alone, the position of these holes is not particularly favourable for the occurrence of heavy minerals, although seams have been reported by Planet Metals Ltd. All are sited close to, or seaward of, the concave change in slope at the base of what appears to be the present-day paralic sand wedge. If this interpretation is correct, the holes were drilled near the base of the beach zone wedge of sand which has built up during the present-day still-stand after the Holocene transgression; the culmination of natural sorting processes taking place during this still-stand is the rich heavy-mineral deposits of the existing beach dune system and only minor concentrations would be expected offshore near the toe of the slope.

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VEEH, H., & VEEVERS, J.J., 1970 - Sea level at -175 m off the Great Barrier Reef 13 600 to 17 000 years ago. Nature, 226 (5245), 536-7.

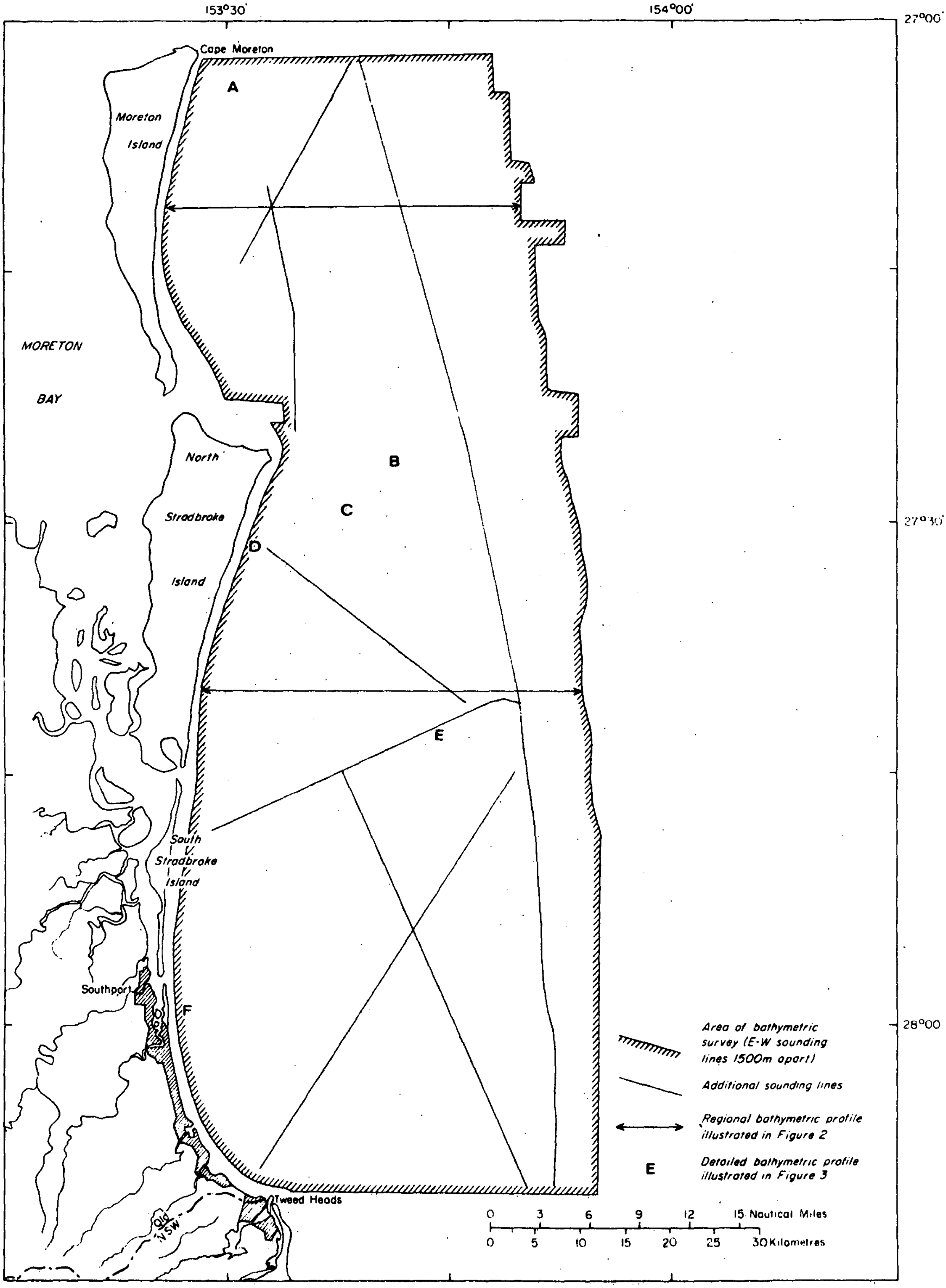
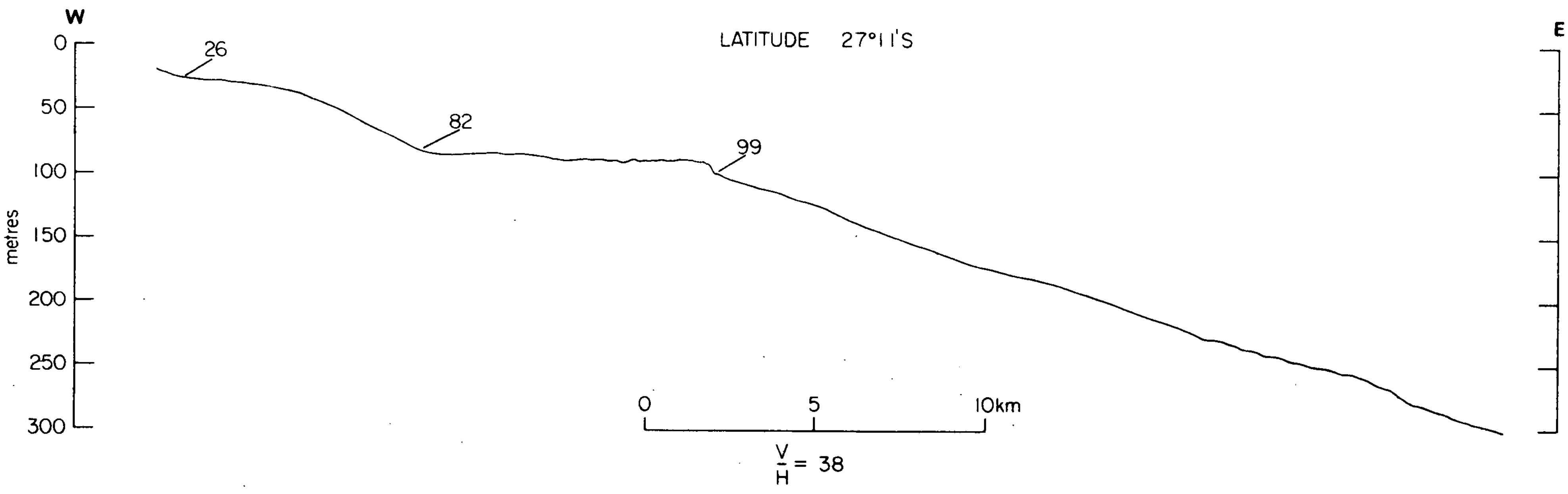


Fig.1. Area of bathymetric survey showing position of tie lines and of regional and detailed profiles illustrated in Figures 2 and 3.



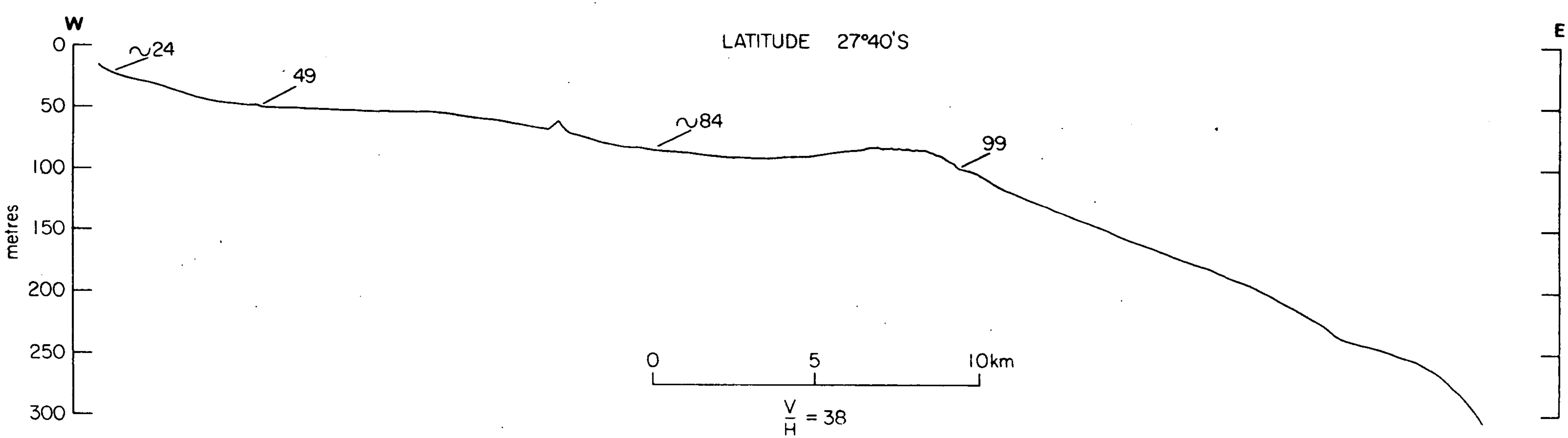


Fig. 2. Generalized bathymetric profiles across the shelf off Moreton Island and off North Stradbroke Island.

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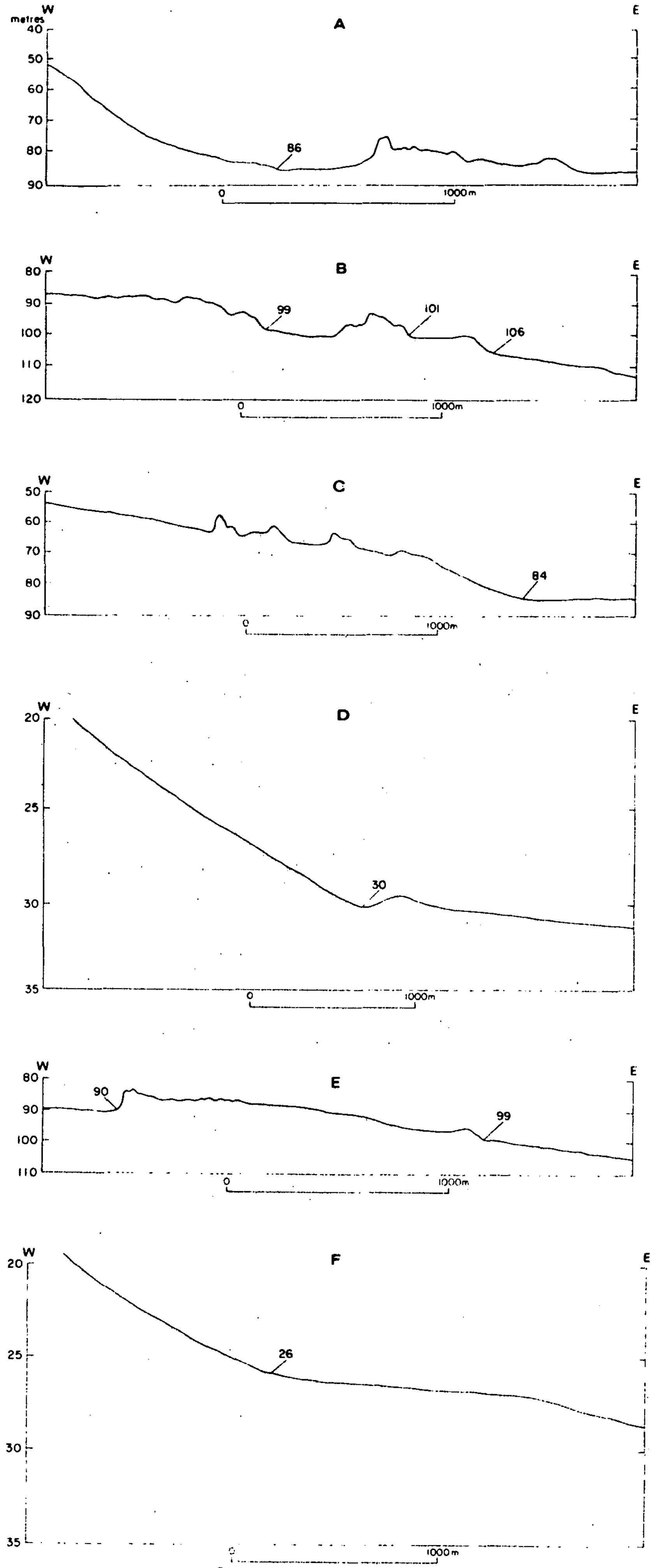

Fig. 3. Tracings of echograms illustrating typical features of shelf morphology. Locations shown in Figure 1.

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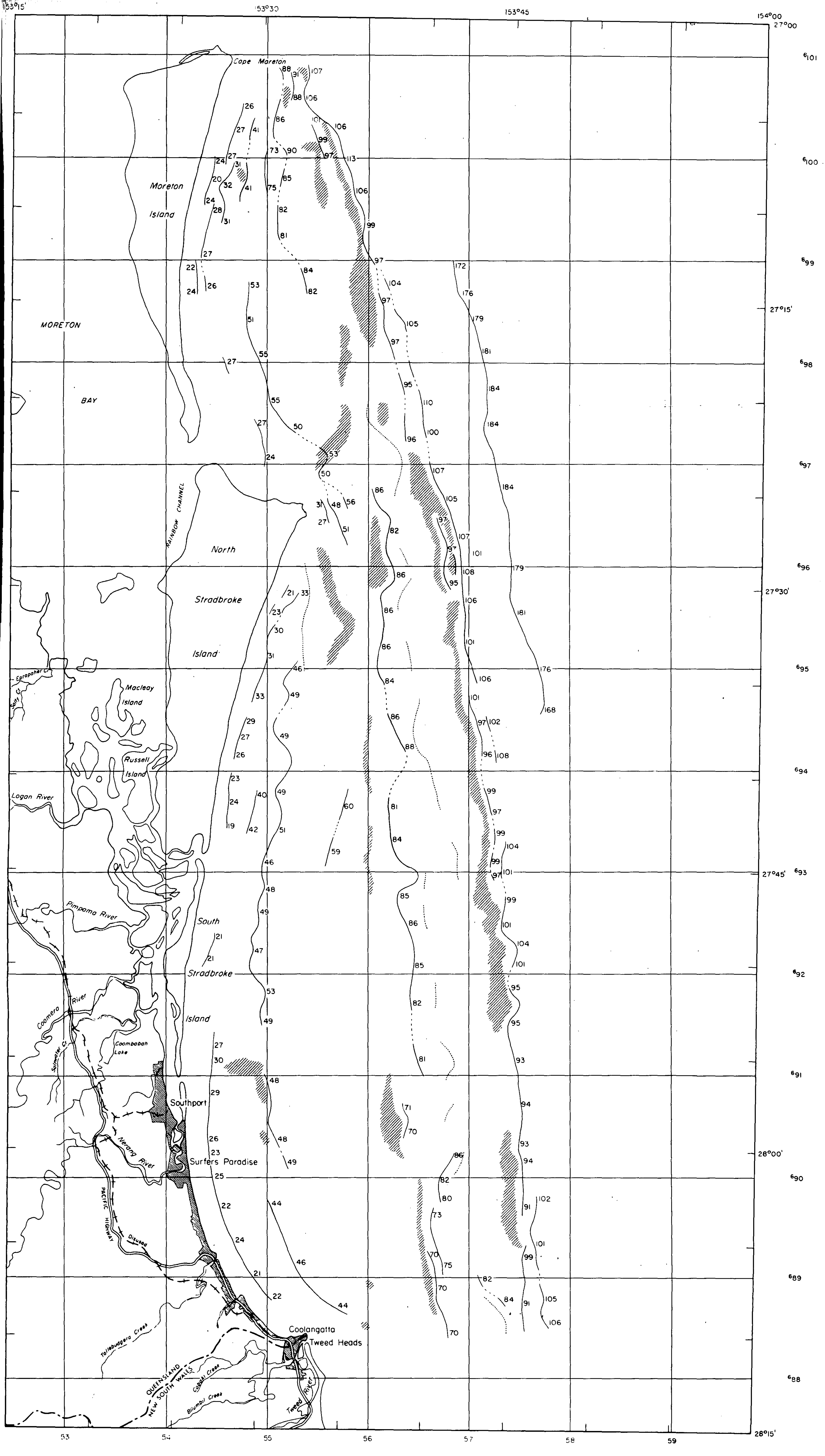

Submerged shoreline with depth to base of change of slope in metres. Broken line indicates continuity is uncertain

Axis of linear depression or channel

Banks, rough ground, commonly elevated

Numbered graticule indicates the 10 000-metre Universal Transverse Mercator Grid Zone 56, Australian National Spheroid

0 5 10 15 Nautical Miles

0 5 10 15 20 25 Kilometres

Plate 1. Morphological features on the continental shelf: Cape Moreton to Tweed Heads.

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