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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1969 / 82

Report on the Australian-Japanese Marine Geological Cruise in the Arafura Sea, May 1969

Survey 192

by

D.S. Trail and H.A. Jones

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS DEPARTMENT OF NATIONAL DEVELOPMENT AUSTRALIA

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SUMMARY

In May, 1969 a B.M.R. marine geology party joined the Japanese Yomiuri oceanographic expedition to carry out bottom sampling, shallow seismic profiling, and deep diving in the southwestern part of the Arafura Sea. Sampling and sparking were carried out along traverses 10 miles apart from the expedition mother-ship, M.V. Yamato on the continental shelf and upper continental slope between 130°E and 131°E. Three dives were made in the small submersible Yomiuri during which drowned reefs were sampled and visual examination of the sea bed made.

The shallow banks of the Van Diemen Rise extend into the northwestern part of the area sampled; elsewhere its surface is a gentle slope extending from Melville Island northwards beyond the 200-metre line, with a number of small breaks between 80 and 180 metres.

North of the quartz sand fringing Melville and Bathurst Islands, a zone of mud expands steadily eastwards to become 70 miles wide at the eastern limit of the area sampled. The mud grades northwards through a zone of very muddy shell sand, about 10 miles wide, into a wide expanse of shell sand with little mud. Brown calcite pellets occur in shell sand off Bathurst Island. All these unconsolidated sediments appear to form a thin cover on older sediments.

Dives in the "Yomiuri" revealed drowned coral reefs at depths of 205 metres, 70 miles north-north-west of Cape Van Deimen, at 180 metres in a submarine valley west of Bathurst Island, and at 140 metres in a valley 170 miles north-east of the Coburg Peninsula. The deepest of these indicates that sea-level has been at least 30 metres lower than the 130-metre level proposed by Van Andel and Veevers (1967).

The co-operative venture was most successful; the drowned coral reefs could not have been examined and sampled without the submersible.

INTRODUCTION

In December 1967, the committee operating the Yomiuri submersible, owned by the Japanese Yomiuri newspaper organization, approached the Bureau of Mineral Resources with a proposal for a joint Australian - Japanese oceanographic expedition in Australian waters in 1968-69. It was decided that in order to make the best use of the facilities offered by the vessels several projects run by different groups of Australian marine scientists should be undertaken; in the 4 months preceding the Bureau's expedition in May, 1969, eight separate research programmes were carried out in the general area of the Great Barrier Reef. Geologists and biologists from the Queensland Department of Harbours and Marine, and the Universities of Queensland, Sydney, Macquarie, and Townsville took part.

The Bureau's programme in the Arafura Sea is a continuation of the systematic geological and morphological study of the continental shelf started in the Timor Sea in 1960 (van Andel & Veevers, 1967) and continued off northwestern Australia in 1967-68 (Jones, 1968). It is intended to continue work in this area during the last quarter of 1969. This report records field descriptions of the sediments and only a preliminary examination of the morphological and structural data has been attempted.

The Bureau party consisting of H.A. Jones, D.S. Trail, and R. Dulski, sailed from Darwin in the mother ship Yamato on the 2nd May and returned on the 12th. During 10 days almost continuous operation, 63 bottom sample stations were occupied and seven sparker traverses totalling a little over 500 miles were run (Fig. 4). Professor Hiroshi Niino of Tokyo University was on board the Yamato during the first part of the cruise.

At Darwin the Bureau's portable laboratory and the profiling system were disembarked and the Yamato sailed with the Yomiuri in tow on the 14th. During the second half of the cruise, during which Dulski was replaced by D. Jongsma, three dives were made in the submersible. The Bureau party finally disembarked at Thursday Island on the 25th May.

Vessels, Equipment and Methods

The M.V. Yamato (Fig.1) is a converted deep sea tug, 336 tons gross and 105 feet overall. Extra accommodation was built into her when she was converted to act as mother ship to the Yomiuri and she has berths for 28 persons. A platform to support the Bureau's portable laboratory was built over the stern of the vessel in Darwin. This position over the propellor resulted in serious, though just acceptable, vibration affecting the profiling equipment.

The Yomiuri (Fig. 2) is 45 feet overall and displaces 35 tons. She has a complementof four plus two observors. She can cruise submerged at 2 knots for 4 to 6 hours, but her emergency life support system has a 60 hour endurance.

Her maximum depth range is 300 metres. Special equipment includes observation ports, 4KW flood lighting, and a mechanical hand for sampling. When submerged she tows a marker buoy on a light line and is in communication with the mother ship by radio telephone. She is robustly constructed and maintains slight negative buoyancy when cruising along the sea bed, with which she comes into frequent, and sometimes quite violent, contact.

Recharging the submersible's batteries takes about 6 hours and must be carried out in sheltered water as the hatch has to be left open while charging is in progress.

All sea floor samples taken from the Yamato were collected with a small conical dredge on a light wire from an electric hydrographic winch on the portside of the foredeck. Wire equal to approximately twice the depth of water was paid out at each station and the ship was allowed to drift in wind and current for several minutes to drag the dredge across the sea floor. The bulk of the sample was caught in a cloth bag attached to the truncated apex of the cone. At some stations two hauls were necessary to collect a minimum amount of about 300 g of sediment. At only one station in the 63 occupied was the amount collected less than this.

The samples were washed into a 2-gallon bucket and allowed to settle for about half an hour. The water was then decanted; a small representative fraction was stored and stained for living material in a small plastic tube with rose bengal and alcohol; the rest of the sample was stored in a glass jar.

The samples were taken at intervals of about 10 miles along seven north-south traverses spaced about 10 miles apart, between longitudes 130°E and 131°E (Fig. 4). The outer limit of sampling was controlled by the wire abailable on the winch; few samples were recovered in waters more than 220 metres deep, although one station was successfully occupied in 298 mtres of water. Sampling was not carried out in water shallower than about 40 metres.

The sparker traverses were made along lines approximating in position to the sample traverses (Fig. 4). Sampling was carried out during the hours of daylight and sparker profiles were run during the night. One sparker traverse was carried out along the approximate edge of the shelf between the first and last sampling traverse and a short profile was also run across a silled basin west of Bathurst Island.

The sparker employed was an Edgerton, Germehausen, and Grier 3-electrode Sparkarray, powered and activated by E.G. and G. power supply and trigger capacitor bank producing a 1,000 watt-record spark. Traverses were recorded on an Ocean Sonics GDR-T recorder which uses 19-inch wet paper. A seven-element MP-7 hydrophone streamer was used, and 100 times linear pre-amplification was inserted between the streamer and the recorder input.

MORPHOLOGY AND STRUCTURE

The morphology of the Timor Sea to the west of the area described in this report has been discussed at length by Van Andel and Veevers (1967). The dominant feature of the eastern part of their area, a region of flat-topped banks separated by narrow winding channels known as the Van Dieman Rise, extends eastwards into the area covered by the present survey. The banks become smaller and more widely separated eastwards and disappear about longitude 130°E (Fig. 5). No banks appear on sparker traverses 6 and 7, along which a gentle slope extends from Bathurst Island evenly down to 82 metres, where there is a slight break in slope. Another slight break occurs at 110 metres on traverse number 7, below which small breaks or benches on the outer shelf occur at 134 metres, 150 metres, and 174 metres on traverse 6, and between 137 and 159 metres on traverse 7. A small break on traverses 3 and 5 lies in about 183 metres of water, and another at 146 metres on traverse 4 (Fig. 6).

The eastern margin of the Van Dieman Rise consists of small banks which appear on traverse 4(Fig. 7). These banks become larger and more numerous westwards to traverse 1, where they form extensive plateaux at depths of 40 to 50 metres. Van Andel and Veevers note that these plateaux resemble the landforms of the Mesozoic and Cainozoic sediments of Melville and Bathurst Islands, and that they are cut by valleys closely similar to Apsley Strait dividing these islands.

The tops of the plateaus are strikingly flat and Van Andel and Veevers have correlated them with surfaces of erosion described in the Northern Territory by Hays (1967). The sparker traverses confirm that this plateau topography is essentially a subaerial erosion surface resulting from the dissection of flat-lying sedimentary rocks. Recent sediments have filled small pockets here and there and smoothed out minor irregularities, but by and large the surface has been little modified since its submergence. Accelerated erosion during the post-Pleistocene transgression and coral reef development have probably been the most important factors modifying the ancient land surface. Figure 8 from sparker traverse illustrates the structures typical of the irregular topography in the western part of the area.

The flat, monotonous continental shelf to the east, however, is an area where sedimentation since the post-Pleistocene transgression has been active. Sparker traverse 7, for example, indicates as much as 300 feet of fill (0.1 secs 2-way travel time) in one shallow depression near the outer edge of the shelf. In general the thickness of Recent sediments overlying the late Pleistocene sub-aerial erosion surface is much less and in most of the profiles is difficult or impossible to assess owing to the lack of structure and absence of strong reflectors below the surface. A short gravity core taken by the Bureau in 1968 north of Cape Wessel, well to the east of the area under review, encountered a fossil soil under only 2 feet of Recent marine sediment. This seems to confirm the conclusions reached by Fairbridge (1966), Van Andel and Veevers (1967), and Van Andel and Tjia (1966), that the thickness of Quaternary marine sediment on the Sahul

Shelf is small, and that the shelf represents an extension of the adjacent Australian continent which has only comparatively recently been submerged.

SEDIMENTS

The area sampled on a 10-mile grid measures roughly 80 miles from north to south and 60 miles from east to west. It extends from the northern coasts of Bathurst and Melville Islands to a little beyond the shelf edge north of these islands. One traverse also extended southwards along the west coast of Bathurst Island.

After processing, these samples will be described in detail together with samples to be collected during the survey of the remainder of the Arafura Sea, which will take place between September and December, 1969. In this report a brief description of the sediments has been compiled from notes made as the sediments were collected on M.V. Yamato.

Mud and Sand

The distribution of the sediments is illustrated in Figure 5. Quartz sand, which forms the beaches of Bathurst and Melville Islands, reaches out to sea as a large shoal extending northwards and westwards from Cape Van Diemen, the northwest point of Melville Island. A narrow zone of mud, which lies to seaward of the sand at Cape Van Diemen, expands eastwards to attain a width of 70 miles north of the central part of Melville Island. The outer limit of this mud zone is marked by a belt of very muddy shell sand, about 10 miles wide, which passes northwards into a side expanse of shell sand, generally with a small proportion of mud, extending beyond the 200-metre line.

The mud is mid grey or mid greenish grey and is generally even-grained. In places it contains scattered shell fragments, and at least some of these represent burrowing molluscs. One sample also contained several live worms and brittle stars or ophiurids. Samples of mud taken on the traverse running north from Cape Van Diemen contain small quantities of quartz sand and traces of glauconite.

The shell sand is closely similar to the skeletal calcarenite described in detail from the adjacent Timor Sea by Van Andel and Veevers (1967). Many of the medium-grained samples from the Arafura Sea appear to be composed predominantly of foraminifera, but many other coarser samples contain abundant fragments of the shells of molluscs and the tests of echinoderms. Professor Niino pointed out that some of the gastropods in samples taken near the 200-metre line were shallow-water forms and that other samples from that region contain abundant pteropods. Van Andel and Veevers note that in the Timor Sea skeletal calcarenite composed of material from molluscs and echinoderms forms an assemblage distinct from skeletal calcarenite composed of small foraminifera.

In the zone of very muddy shell sand, the mud is evenly distributed among the shell fragments. In a few samples of shell sand from the outer part of the continental shelf the mud forms small lumps or soft pellets, a few millimetres across, which may represent layers rolled up in the dredging process.

Small pebbles and granules of brown fine-grained material, common in shell sand off the north and west coasts of Bathurst Island, strongly resemble pisolites of ferruginous laterite, but Van Andel and Veevers (1967) found that they are composed of very pure calcite and contain very little iron; they note that some of the smaller grains have formed around a nucleus of quartz. They suggest that these calcite pellets formed in situ during the subaerial exposure of the shelf in the time of the latest (Wisconsin or Wurm) glaciation.

The only sediment that can be readily identified in a preliminary examination of the sparker records is the mud. This forms an extensive apron which has a maximum thickness of about 50 feet at the landward end of traverses and which tapers away seawards gradually but steadily to be replaced by the shell sand; the sand appears to be so thin that it is not easily identified on the sparker records. Along sparker traverse 4 the mud wedge abuts against a small bank. (Fig. 9).

Dives in the Yomiuri have confirmed that the valleys are floored by mud and that a continuous cover of shell sand surfaces the plateaux west of Bathurst Island. Also that the sea floor in the vicinity of the 200-metre line is covered by a layer of shell sand with only a small mud or silt fraction.

Coral Reefs

Drowned coral reefs were identified in all three dives made in the Yomiuri. The first dive was over a 200-metre silled trough about 15 miles northwest of Cape Fourcroy, Bathurst Island; the second was on the outer edge of the shelf 75 miles north-north-west of Cape Van Diemen; the the third was again close to the shelf edge, 140 miles northeast of Port Essington. (Figs 3&4).

The reefs were sampled on the second and third dives. On the first dive coral was positively identified only at the deepest outcrop, at 180 metres, where the rock could be examined closely through the bottom port of the submersible (Fig. 10). Diving conditions were very poor during this dive; strong bottom currents stirred up sediment reducing visibility and hindering manoeuvrability, while swarms of tiny fishes gathered around the Yomiuri's lights, further hindering observation. The two higher outcrops visited on this dive are probably reefs, but may be bedrock composed of older Cainozoic or Mesozoic sediments, which crop out on Bathurst Island nearby.

The steep slopes below most reefs examined are commonly covered by coral debris extending downwards for several metres.

Above the outcrop, the angle of slope decreases markedly to a gentle rise covered with shell sand containing scattered boulders of coral. The drowned reef observed on the second dive faces north and the shell sand has been scoured out in front of it to a depth of 13 metres. From the bottom of the scour to the top of the coral cliff, the feature is 20 metres high (Fig. 11a,b).

The drowned reef located on the third dive forms the crown of the north wall of a submarine valley. Again the valley is floored by mud and the valley wall is surfaced by coral scree and shell sand for at least 30 metres below the outcrop of the reef.

Guilcher (1958) and Fairbridge and van der Linden (1966) agree that reef coral grows only in shallow water. The former sets a lower limit of 15 fathoms for surface reef species and the latter a lower limit of 20 metres for the growth of extensive reef patches. Fairbridge (1966) notes that coral reefs have been located in depths of 400 to 600 metres in the Arafura Sea, and he views this as an indication of active subsidence of the margins of the sea.

Van Andel and Veevers (1967) place sea-level between 60 and 70 fathoms (110 to 130 metres) in the Timor Sea at the maximum regression during the last glaciation. They state that a rediocarbon date on silty calcareous clay collected by them "confirms the presence of a shallow nearshore environment at 72 fathoms some 17,000 years ago." They continue "this low stand of sea level is marked by a break in slope generally accompanied by a low cliff with its base between 60 and 70 fathoms". The sparker records made in 1969 confirm that the most persistent feature on the outer shelf is a step at about 130 metres (70 fathoms). A deeper feature at 205 metres , identified in the second dive (Fig. 11a, b), is not so persistent but appears in sparker traverses 3 and 5. On records of both these traverses it appears to lie in about 180 metres of water, but the echo-sounder on M.V. Yamato and the depth gauge on the Yomiuri indicated a depth of about 205 metres for this feature. The sparker profiles and the diving and echosounding were carried out at different times and fixing of relative positions to within better than 2 miles cannot be expected. It is possible that local displacement of the feature by faulting has occurred, but an error in the recording equipment is also feasible. The correct depth of this feature will be established at a later date.

A sample of coral collected by the Yomiuri from the 205-metre reef is currently being processed for radiocarbon dating. Van Andel and Veevers do not think that much subsidence has taken place since the maximum of the last glaciation. The existence of this reef at a depth about 50 metres below the depth of the shoreline feature found by Van Andel and Veevers suggests that sea level was at least 30 metres lower than the lowest depth suggested by them.

Van Andel and Veevers also obtained a sample with the shallow-water shell Lima persquamifer from 290 metres, which gave a radiocarbon date of 23,800 years before present. They thought this sample was probably displaced, but it may indicate a sea-level considerably lower than 132 metres. A sea-level around 200 metres would also have enabled rivers to cut the floors of the valley west of Bathurst Island and of the Malita Shelf Valley to the depths shown by Van Andel and Veevers in their bathymetric chart of the Timor Sea.

ACKNOWLEDGEMENTS

This cruise in the Arafura Sea was made possible by Mr. M. Shoriki, head of the Yomiuri Shemban organization of Tokyo which owns the Yamato and the Yomiuri. The success of the operation was in large measure due to the high standard of seamanship shown by Commander Ohba and his crew, and to the full and willing co-operation which they extended to the Bureau party at all times. Professor Niino's wide experience in marine geology was also of great value to the Bureau geologists. This venture is a most rewarding example of international co-operation in the field of oceanography.

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Fig. 1. M.V. Yamato. The Bureau's portable laboratory, not shipped when this photograph was taken, was mounted over the stern.

Fig.2. The submersible Yomiuri.

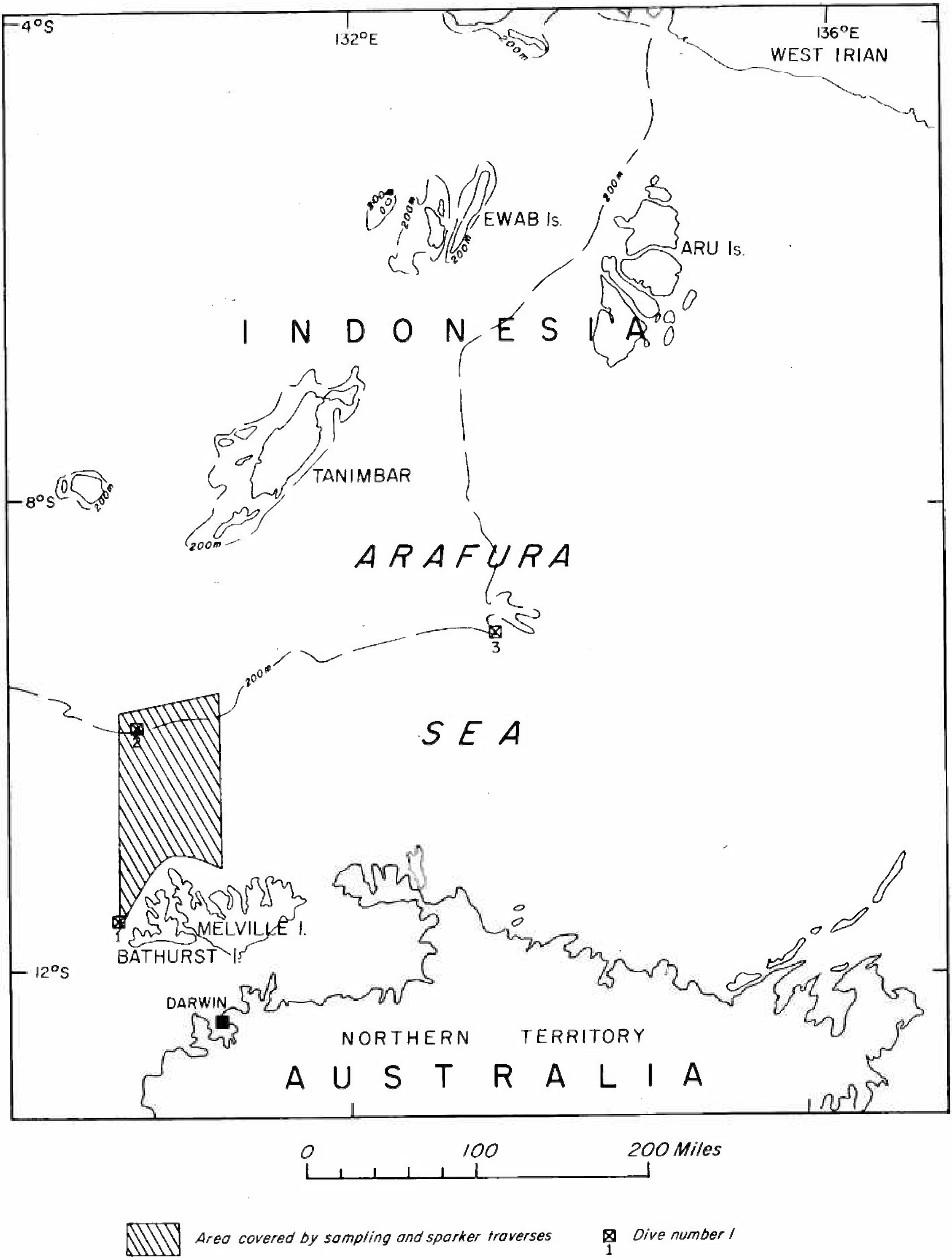
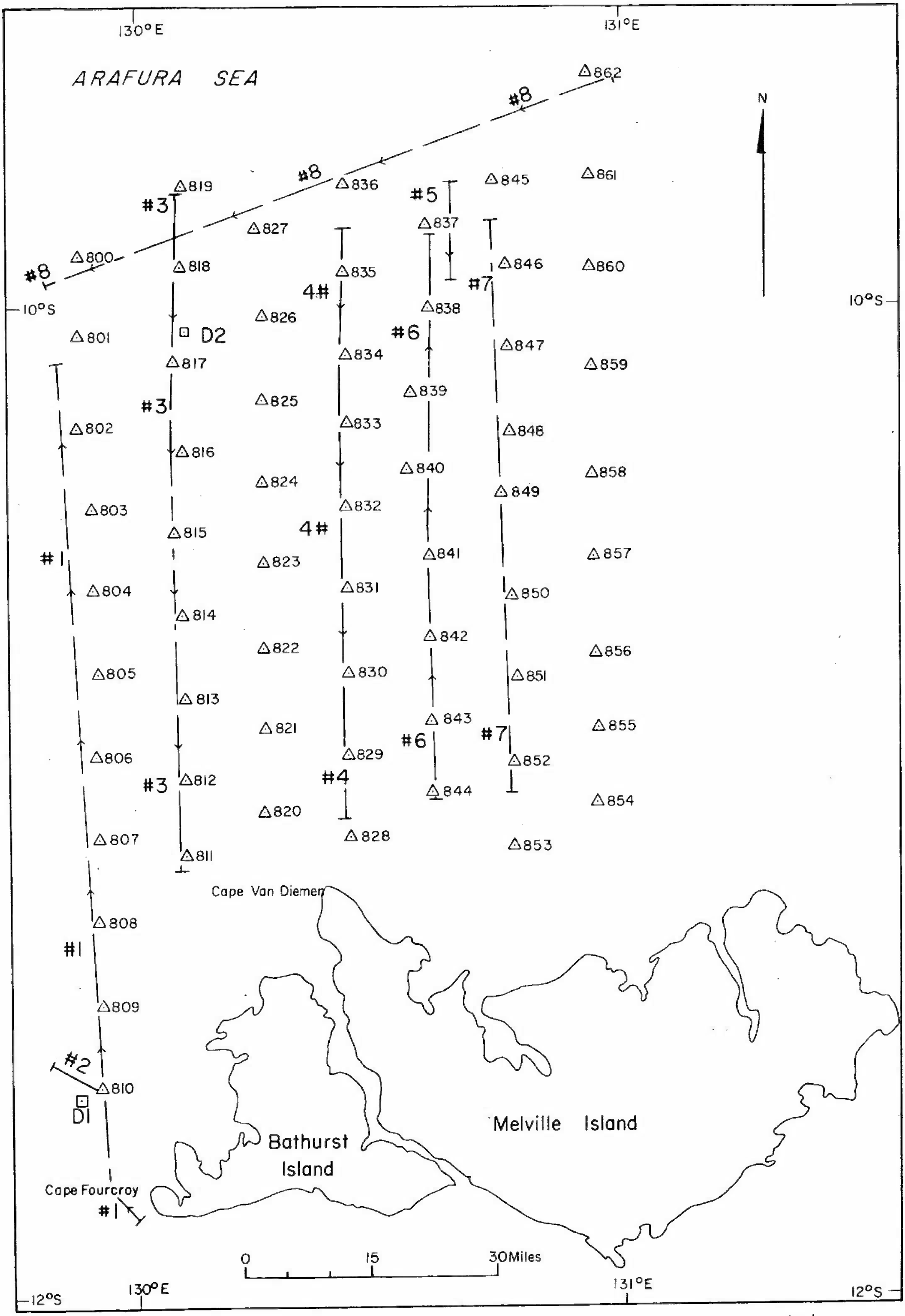


Fig. 3 General Location of Area Sampled in M.V. 'Yamato' and of Dives in Submersible 'Yomiuri'.



Δ801 *Bottom sample*

⊡ *Location of dive*

Sparker traverse(showing start,finish and direction)

Fig. 4 Location of Samples, Dives, and Sparker Traverses, Arafura Sea, May, 1969.

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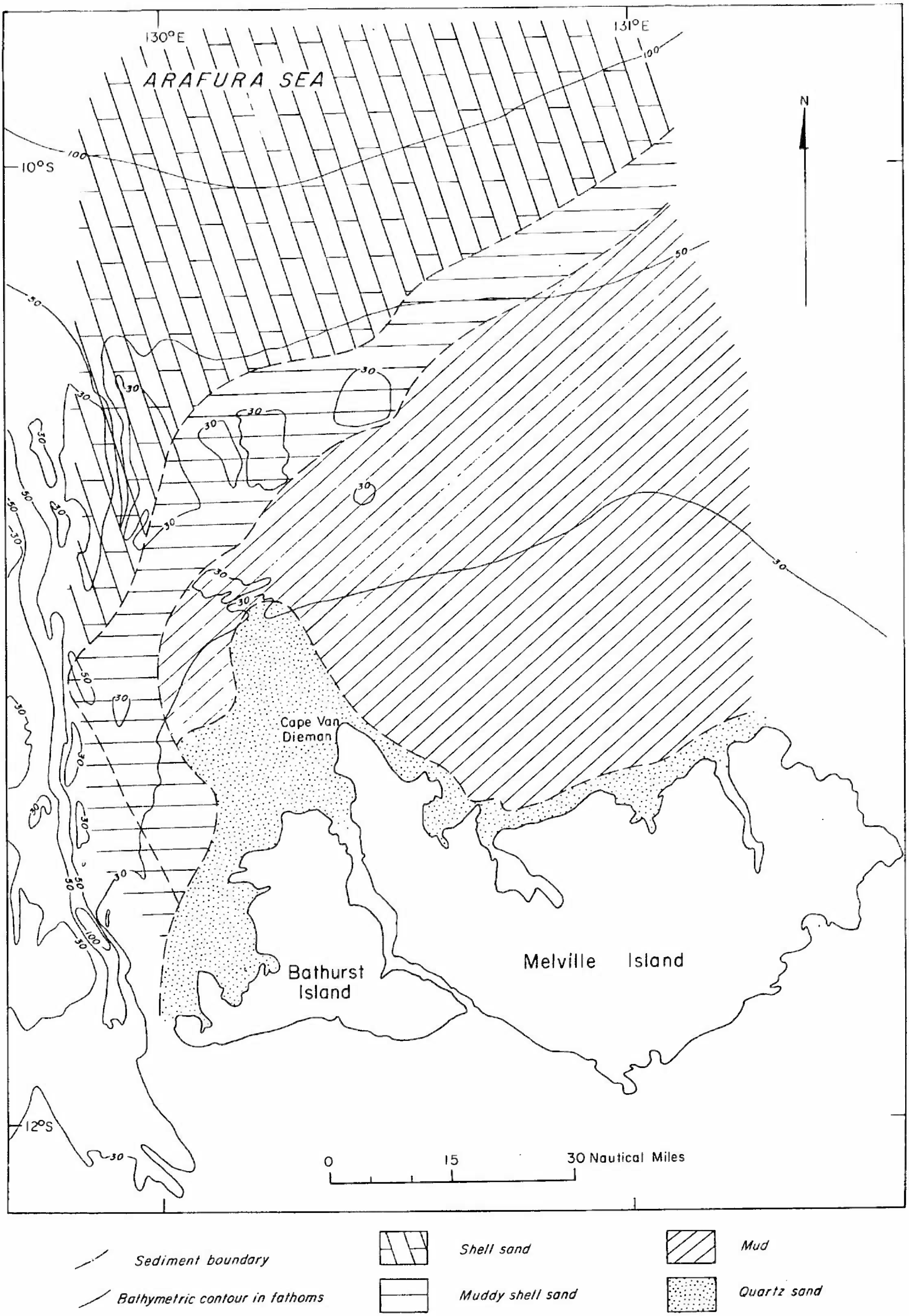

Fig.5 Sediments and Morphology in the Arafura Sea North and West of Melville Island
(Morphology from van Andel and Veevers, 1967)

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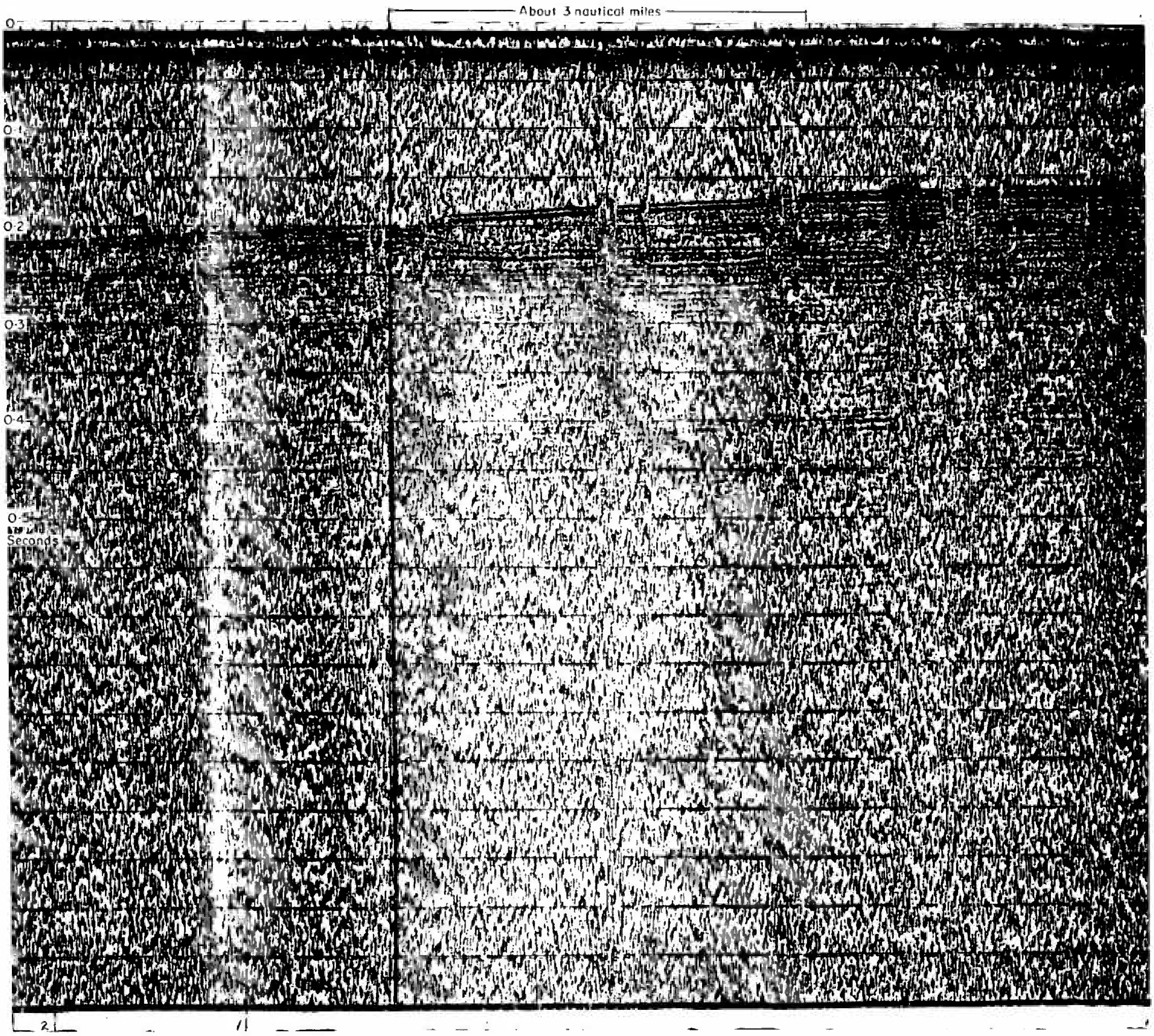

Fig.6 *Small break at 140 metres on sparker traverse 4*

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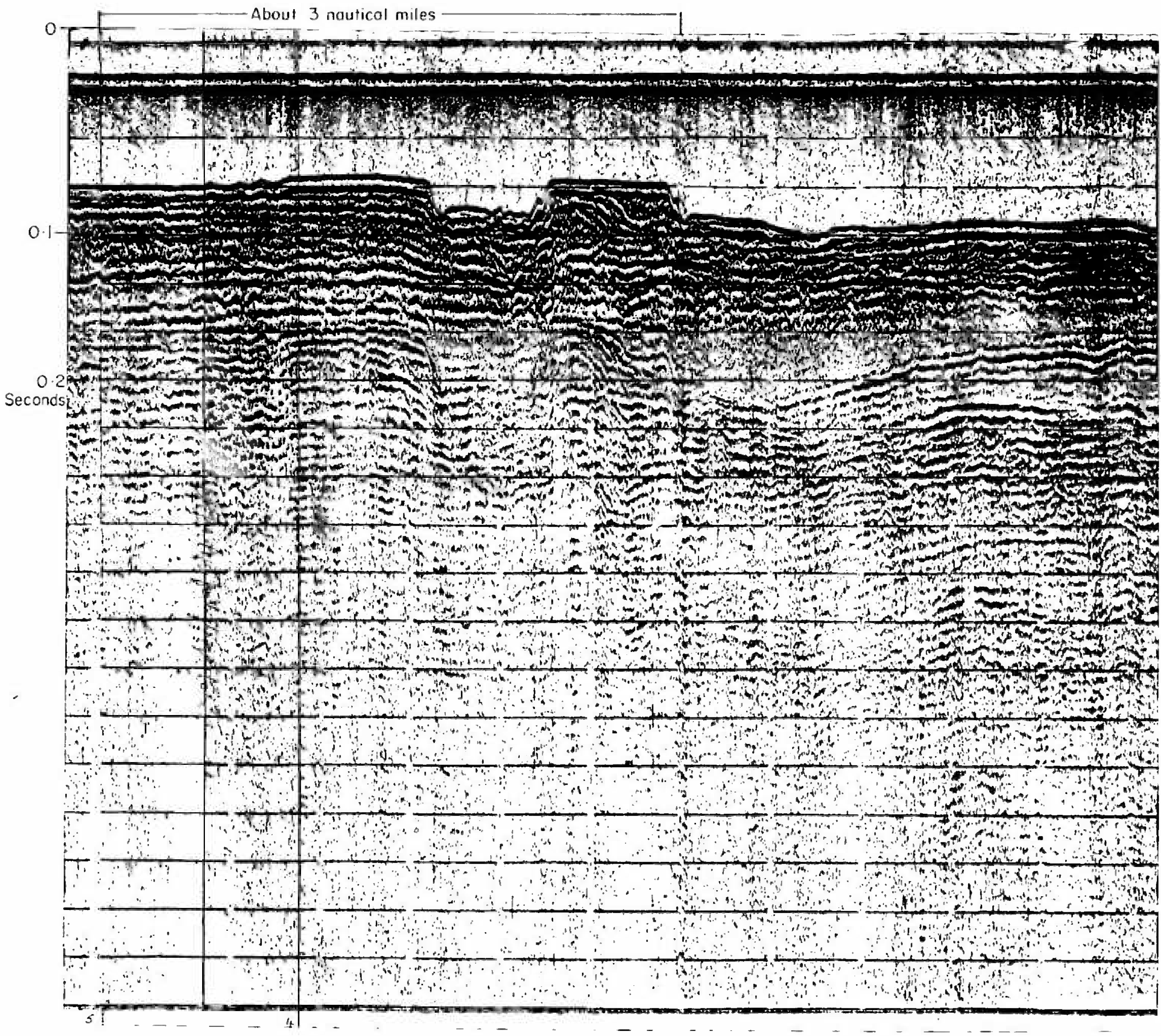

Fig. 7 *Small banks at 50 metres depth on sparker traverse 4, at eastern end of Van Diemen Rise. One plateau is partly formed by fill of younger sediments.*

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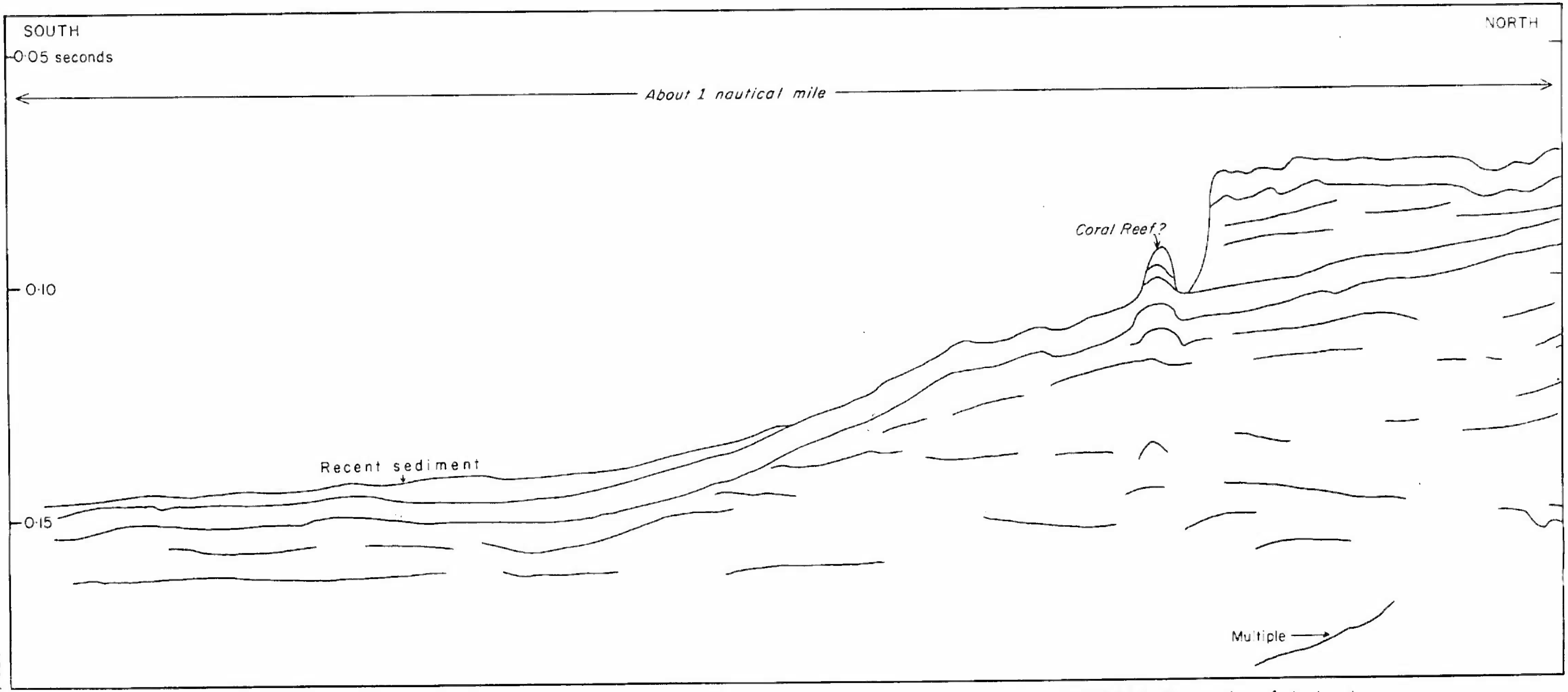

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Fig 8 Line-drawing interpretation of part of sparker traverse 1. Plateau surface is at about 55 metres depth. Note truncation of strata at plateau edge and the strong reflector under the plateau controlling the sea floor to the south. This reflector dips below the recent sediment to the south.

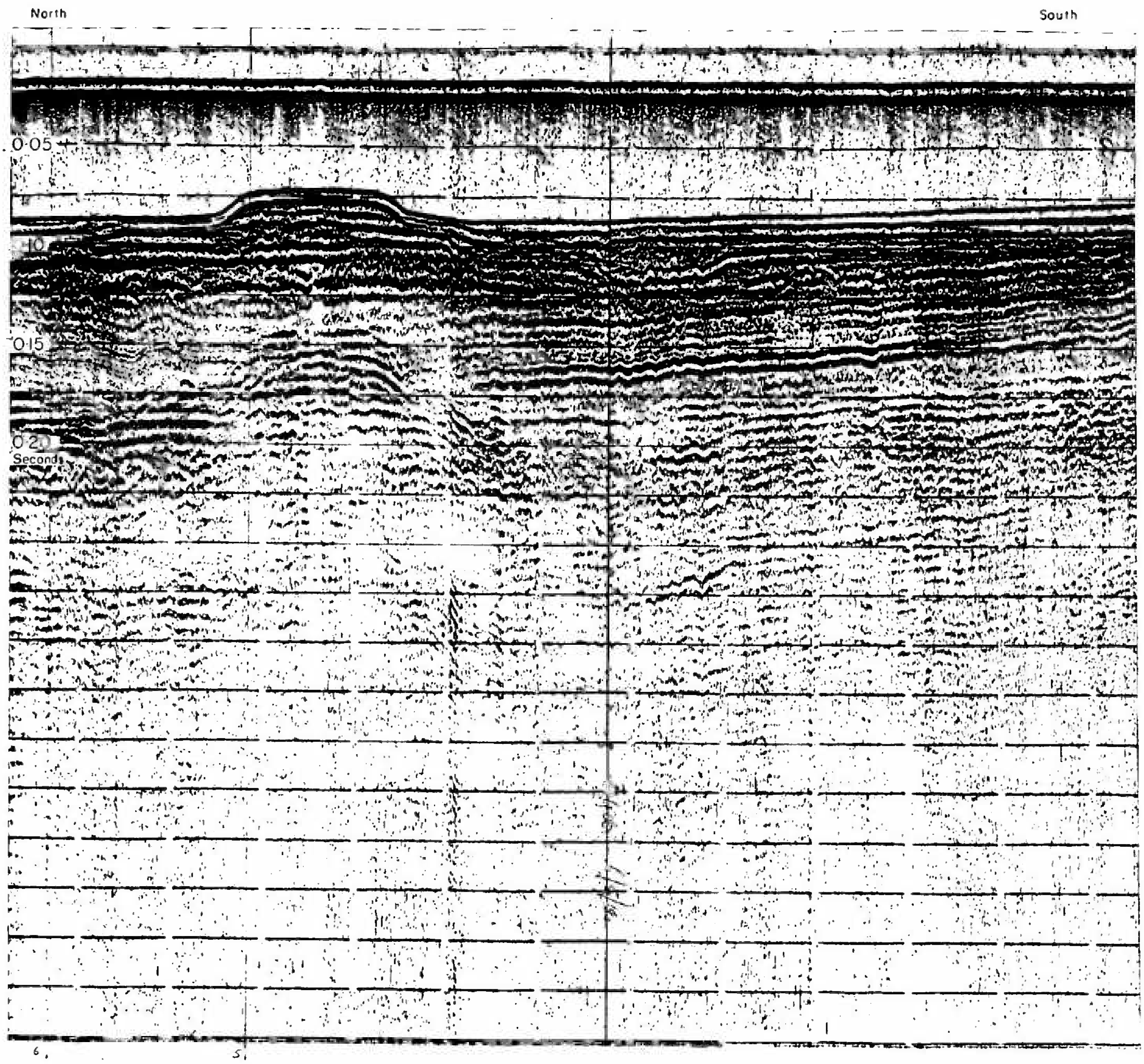

Fig.9 *Mud apron from south wedges out against a small bank, on traverse 4. The bank top is at 50 metres depth.*

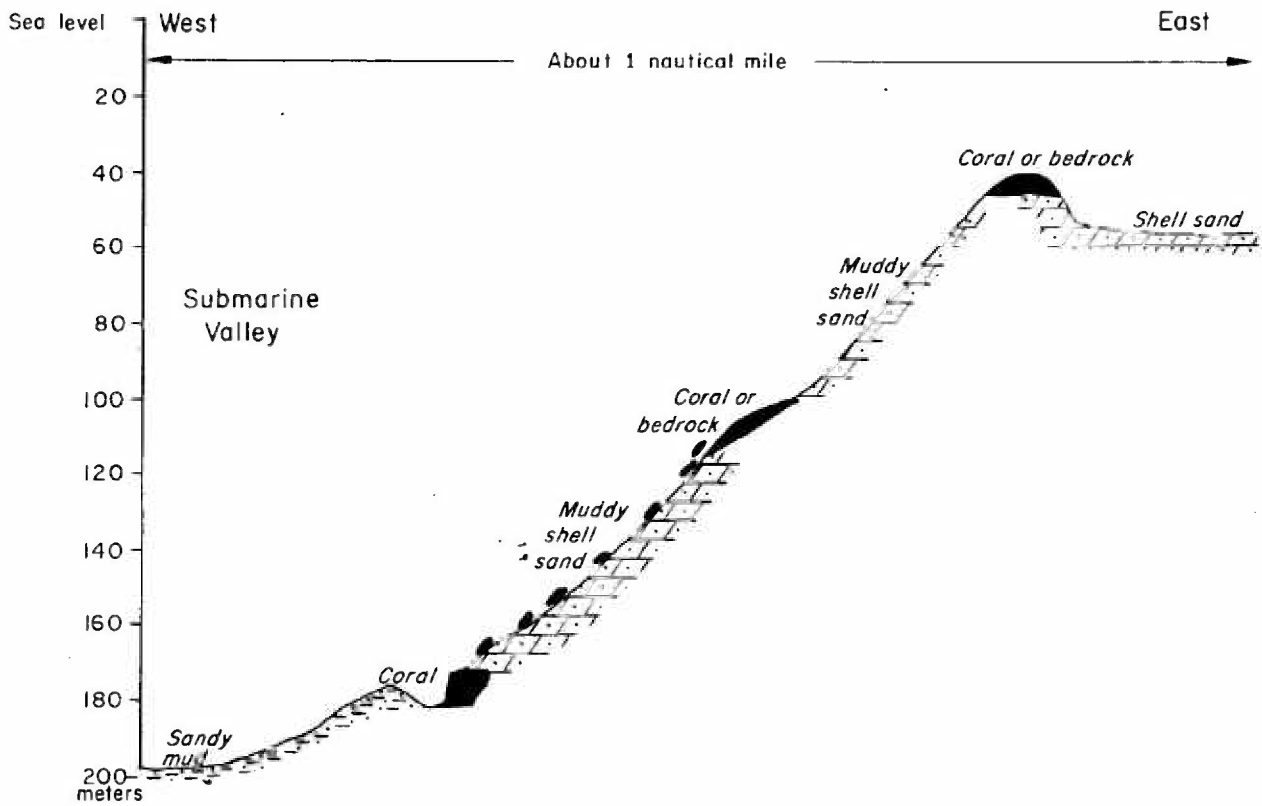

Fig. 10 Profile along course of first dive.

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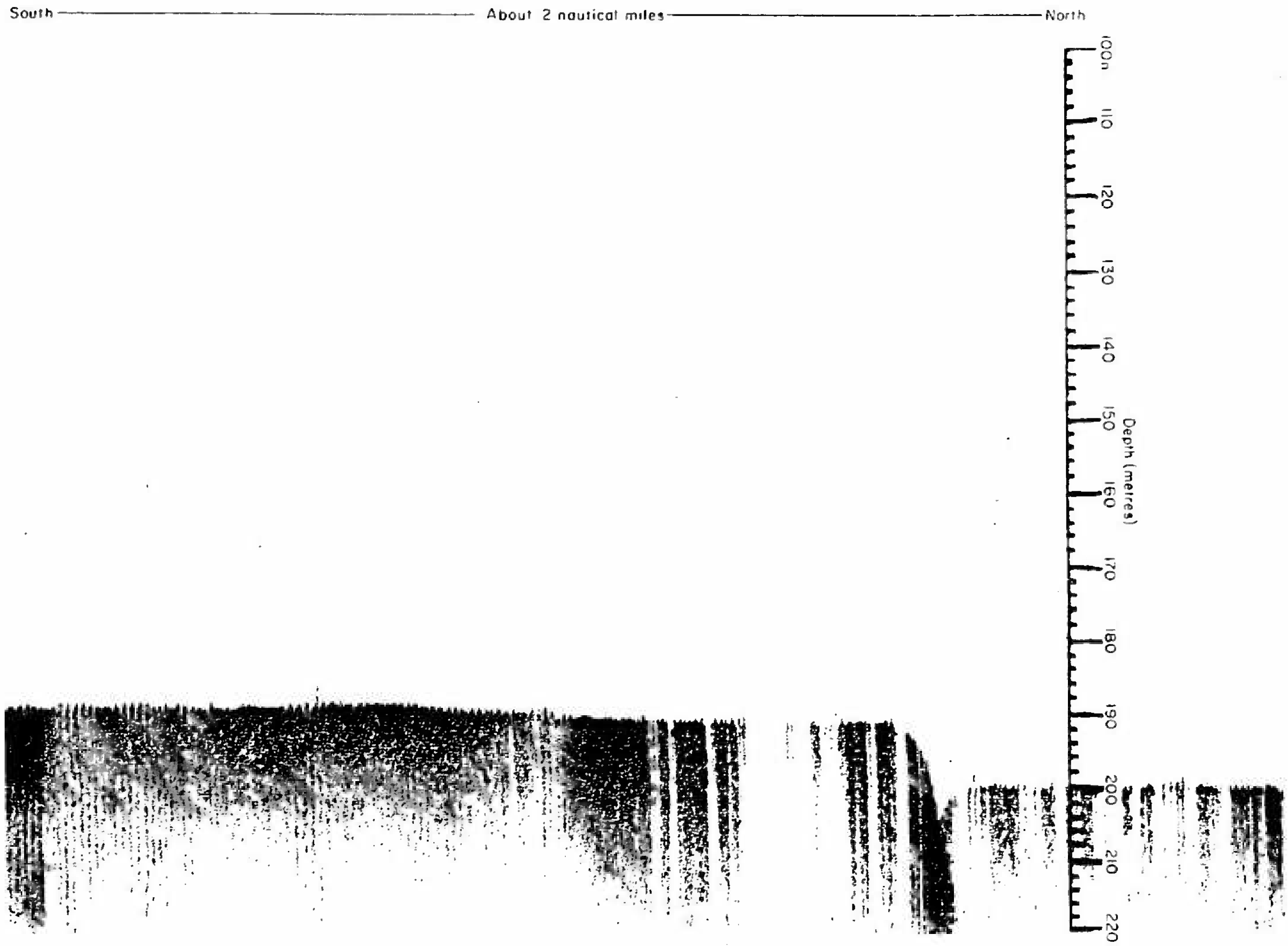

Fig 11a Echo — sounder traverse in vicinity of second dive

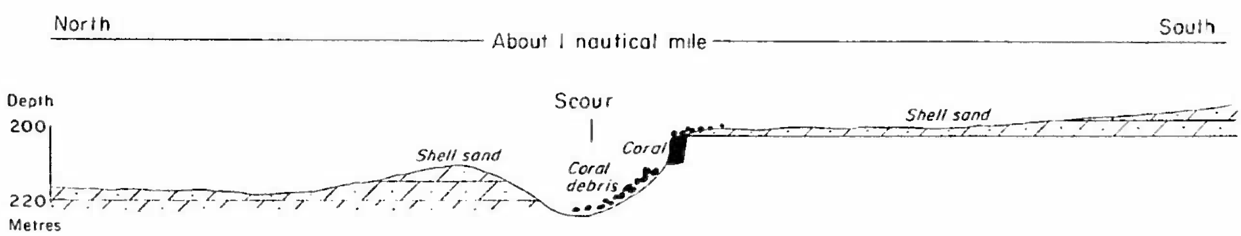

Fig. 11b Profile along part of course of second dive. (From a sketch by D. Jongsma)

To accompany Record 1969/82 C52/A/10

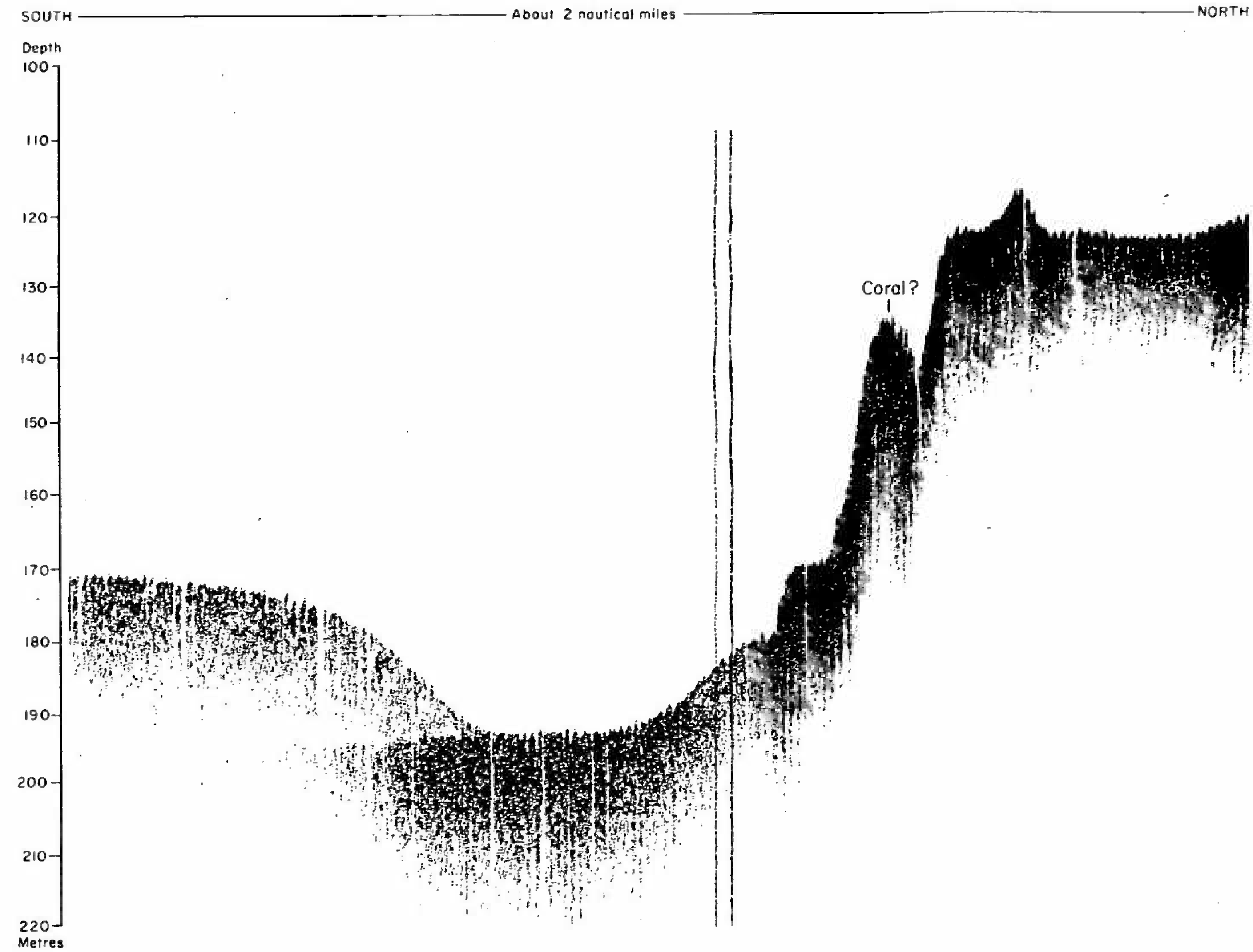

Fig. 12a *Echo—sounder traverse in vicinity of third dive*

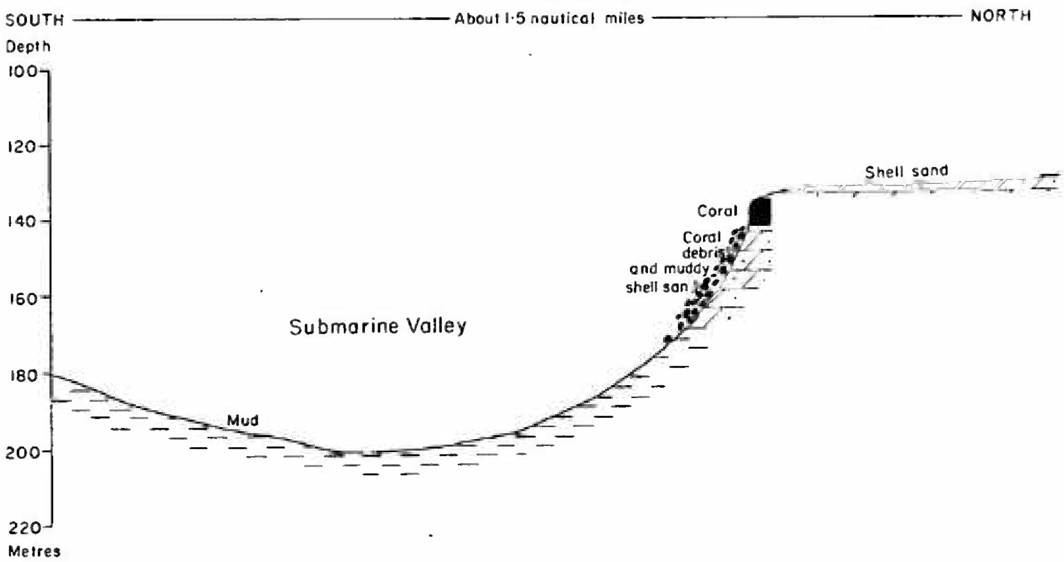

Fig. 12b *Profile along course of third dive (from a sketch by D. Jongsma)*