COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1968 / 84

A Preliminary Account of the Sediments and Morphology of Part of the North-West Australian Continental Shelf and Upper Continental Slope

by

H.A. Jones

Survey 138

A PRELIMINARY ACCOUNT OF THE SEDIMENTS AND MORPHOLOGY OF PART OF THE NORTH-WEST AUSTRALIAN CONTINENTAL SHELF AND UPPER CONTINENTAL SLOPE

by

H.A. Jones

Record 1968/84

CONTENTS

TABLE

PLATES

FIGURES

FIGURES (Cont.)

SUMMARY

This report gives the preliminary results of a survey of the superficial sediments of the continental shelf and upper continental slope off north-western Australia between latitudes 13°S and 18°30'S. One hundred and sixty-three bottom sample stations were occupied; continuous bathymetric profiling and underwater photography were also carried out.

The break in slope at the outer edge of the shelf lies at a depth of 120 metres in the northern part of the area, shallows to 60 to 80 metres due west of Cape Leveque, and deepens again to 140 to 160 metres south-east of the Rowley Shoals. These variations in depth indicate Recent warping of the continental margin.

The morphology of the shelf itself is less complex than that of the Sahul Shelf to the north-east and terraces indicating still-stands during the post-glacial rise in sea level are not developed. This is particularly true of the southern part of the area surveyed where the shelf forms a gently sloping surface almost completely lacking in relief. The more irregular sea bed topography to the north reflects to some extent erosional features of the buried resistant rocks of the Kimberley block. Uneven coral reef development contributes to the irregularity of the shelf in the northern part of the area and further masks the structural history.

Calcareous sediments are completely dominant on the continental shelf. The terrigenous detritus does not make a significant contribution to the surface sediments anywhere in the area sampled except close inshore in the approaches to York Sound, and the non-calcareous authigenic components - glauconitic clays and phosphate - are always minor. Most of the carbonate is of organic origin but oolite development is well marked over wide areas of the outer shelf. A high proportion of the calcareous sediment in some areas of the shelf consists of planktonic foraminifera, a clear indication of the slowness of deposition, whilst elsewhere the sea bed is formed of relict, shallow water, coarse, shell detritus indicating that no sedimentation has occurred since the post-Pleistocene transgression.

Phosphate, in the form of sand-size collophane pellets, shell replacements and infillings, and impure collophane-clay-carbonate material is a widespread but minor constituent of the surface sediments. It is most abundant on the upper continental slope at depths of 250 to 300 metres, but the highest P_2O_5 value recorded was 10 percent and most of the phosphatic sediments contained 2 percent or less. These values refer to the fine fraction recovered; the superficial sediments invariably include shell material and concretionary carbonate and the P_2O_5 content of the bulked material would not exceed half the values quoted.

INTRODUCTION

Purpose and scope of the investigation

The reconnaissance survey of the superficial sediments of the continental shelf and upper slope of an area off north-western Australia described in this report is the first such venture independently mounted by the Bureau of Mineral Resources. It follows the successful cruises carried out by the Scripps Institution of Oceanography and the B.M.R. in the Timor Sea as part of Scripps' contribution to the International Indian Ocean Expeditions in 1960-61, and it is hoped that it will in turn be followed by further marine geological investigations by the B.M.R.

The purpose and scope of the present investigation were to map the distribution of bottom sediments in an area of continental shelf chosen, on the limited information available, for its phosphate potential, to describe the sediments, and to establish the various factors controlling their distribution. The location of the area studied is shown in Figure 1. A study of the foraminifera of the samples is also in progress.

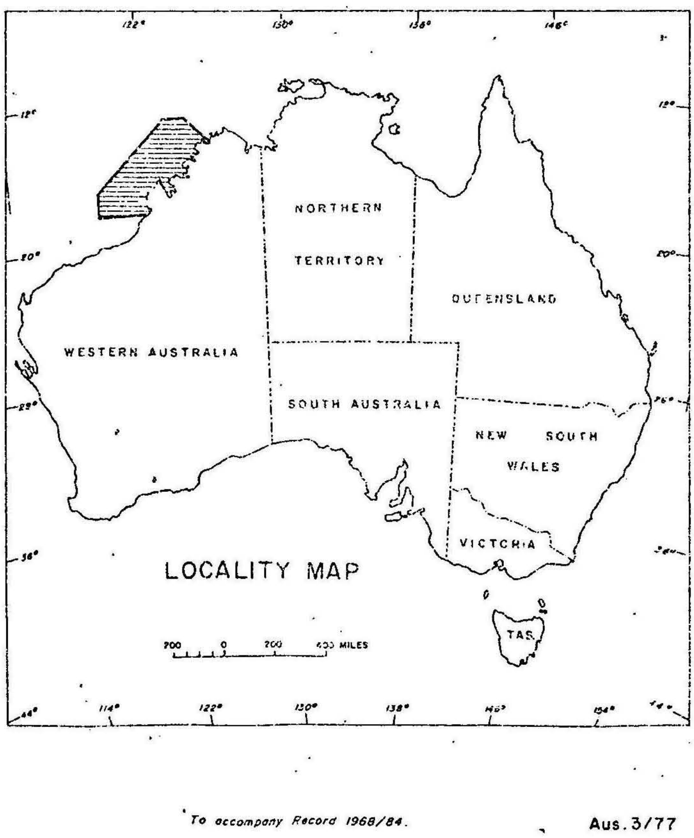


Figure 1: Location map

The survey started on 22nd October and finished on 4th December 1967.

It is planned to extend the area surveyed to the North West Cape - Montebello Islands area in 1968, and the results presented in this report are preliminary and incomplete. A later publication will give a description of the whole shelf between the Timor Sea and North West Cape, and in addition to a more detailed description of the sediments, it will include some seismic data from a geophysical survey planned by B.M.R. for late 1968.

Vessel

The vessel used for the survey was the 125-foot steamship Kos II chartered from Tuna and Trawling Industries Pty Ltd, Brisbane. The Kos II, about 250 tons displacement, was built in England in 1929; designed as a whale chaser, the ship was of steel construction with a beam of 24 feet and a draft of 10 feet forward and 14 feet aft when laden. Propulsion was by a triple expansion steam engine driving a single screw giving a cruising speed of about 9 knots. Although steam has advantages over diesel in a survey vessel from the point of view of quietness, lack of vibration, and ability to run continuously at low revolutions, the engine and bunkers take up so much space that accommodation and working space available are much less than in a motor vessel of similar hull dimensions.

As might be expected in a vessel nearly 40 years old which has not been extensively refitted, mechanical breakdowns and failures of gear occurred. However, the low freeboard and firm underwater lines (Fig. 2A) gave the Koss II a stability at sea remarkable in a vessel this size; this is a great advantage in a ship used as a platform for a marine geological survey and to some extent outweighed the shortcomings of the vessel in other respects.

During the survey 6 days were lost as a result of mechanical breakdowns on board and 1½ days on account of injury to a member of the B.M.R. party at sea. No time was lost due to bad weather.

Climate

The dominance of the south-east trades during the winter months and north-west monsoon during the summer, although well marked, is not so over-riding in this area as it is in the Timor and Arafura Seas to the north-east. According to the Australia Pilot Vol. V., the period of south-easterlies is rather shorter than it is in lower latitudes and there is a tendency, which increases south-westwards, for the summer north-westerlies to back

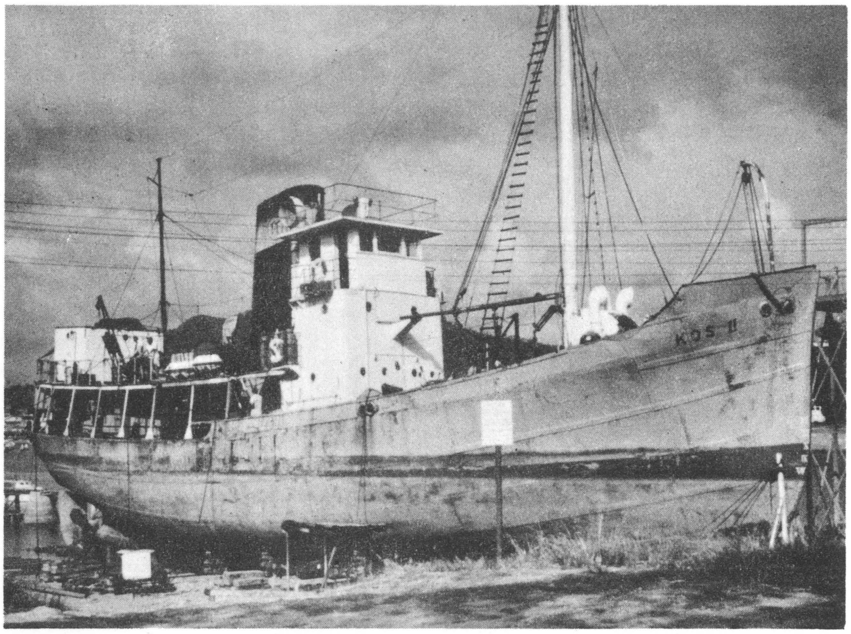


Figure 2A. The Kos II on the slip at Townsville. The portable laboratory can be seen on the upper deck aft. Dredging was carried out on the foredeck using the boom on the main mast.

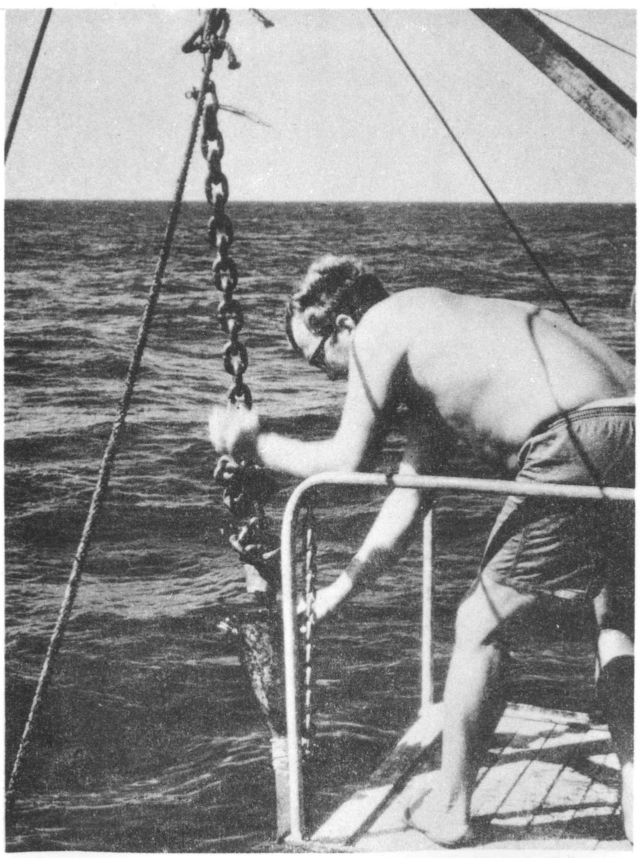


Figure 2B. A small conical dredge with sample bag attached being operated from a platform over the side of the vessel.

to west, and even to south-west, in the region of the Rowley Shoals. Further to the south-west again, off N.W. Cape outside the area under review, southerlies predominate throughout the year.

Between the two seasons there are periods, usually lasting several weeks, when winds are light and variable and, in the case of the spring transitional period, when the mean cloud cover is very low. The present survey took place during the spring transitional period from October to December, and these optimum weather conditions were experienced. Only one squall reaching gale force was recorded during this period.

TABLE 1

METEOROLOGICAL STATISTICS AT BROOME[1]

MONTH	Temperature Av. Daily Max °F	Av. Daily Min °F	Cloud Cover (Oktas)	Wind Direction[2] Percentage Observations from N	NE	E	SE	S	SW	W	NW	Calm	Rainfall (In)
JANUARY	92	79	3.8	8	5	6	8	10	26	22	11	4	6.7
FEBRUARY	92	79	4.0	6	1	6	11	15	31	18	8	4	5.6
MARCH	93	78	3.0	9	6	17	25	10	13	11	5	4	3.6
APRIL	93	72	1.7	2	2	39	39	10	2	2	1	3	1.0
MAY	86	65	1.4	2	4	37	42	11	1	1	1	1	1.0
JUNE	83	60	1.4	1	2	38	42	7	6	2	0	2	0.4
JULY	82	57	1.0	2	3	29	44	10	3	2	2	5	0.2
AUGUST	86	59	0.7	3	5	25	37	18	4	4	1	3	0.1
SEPTEMBER	89	65	0.7	3	3	13	36	21	11	9	3	1	0.0
OCTOBER	91	72	1.0	4	1	7	20	24	24	13	6	1	0.5
NOVEMBER	93	77	1.6	1	1	5	14	16	23	22	10	8	0.3
DECEMBER	94	79	3.0	4	4	9	12	13	26	15	11	6	2.5
MEANS	89	70	1.9	4	3	19	28	14	14	10	5	3	Total 21.9

1 Based on from 5 to 46 years observations since 1911. Data from Australia Pilot Vd. V.

2 Taken at 0900 hours. Afternoon readings show greater spread due to sea breezes.

When considering the climatic statistics for Broome (Table 1), it should be noted that the effect of land and sea breezes at coastal stations is very strong and tends to mask the influence of seasonal winds offshore. Sea breezes, blowing from the sea to the land, occur during the daytime; they may reach force 5 on the Beaufort scale during the afternoon and extend 20 miles or more out to sea. The nocturnal land breeze seldom exceeds force 4 and its influence is not felt more than 5 miles out to sea.

Oceanography

Information on surface water circulation patterns in this area is very incomplete. According to generalized surface current atlases of the south-eastern Indian Ocean (see, for example, the Australia Pilot Vol. V, US Navy Hydrographic Office Special Publication 53, and Wyrtki, 1961), the surface circulation off Western Australia is dominated by the West Australian Current, which originates in about 30°S. latitude as a branch of the east-flowing Southern Ocean Current. The West Australian Current sets northwards to about 20°S latitude where it swings north-westwards, being maintained by the south-east trades, and eventually joins the west-flowing South Equatorial Current far out in the Indian Ocean in about 105°E. longitude (Figure 3). This picture is not fully confirmed by a study of the monthly resultant currents published by the U.S. Hydrographic Office or by the conclusions of C.S.I.R.O. workers, for example Wyrtki (1962), Hamon (1965), Rochford (1967), which indicate a much more variable circulation pattern. In any event, in the area of the present survey, the effect of tidal streams is dominant.

The tidal range along the north-west Australian coast increases irregularly northwards from about 7 feet at Onslow to 19 feet at Port Hedland, 28 feet at Broome, and 33 feet at Derby. The rate and direction of tidal streams are largely controlled by local coastline and seabed morphology. Tidal streams are often strong inshore and rates of up to 10 knots have been recorded in the approaches to King Sound. Rates decrease rapidly seawards but currents of 1 to 2 knots are still met as far out as the edge of the continental shelf where, during the strength of the tide in calm weather, surface rips and overfalls mark the break of slope of the sea bed. The tides are mainly semi-diurnal in character; the flood tide usually sets between south and east and the ebb between north and west, but even well offshore directions may be very irregular, particularly in shoal waters.

Hydrological and productivity observations have provided some evidence of upwelling off the north-west Australian coast (Rochford, 1962; Tranter, 1962; Wyrtki, 1962. See also the discussion in Van Andel & Veevers, 1967). Surface water circulation would appear to favour upwelling along the margins of the north-west

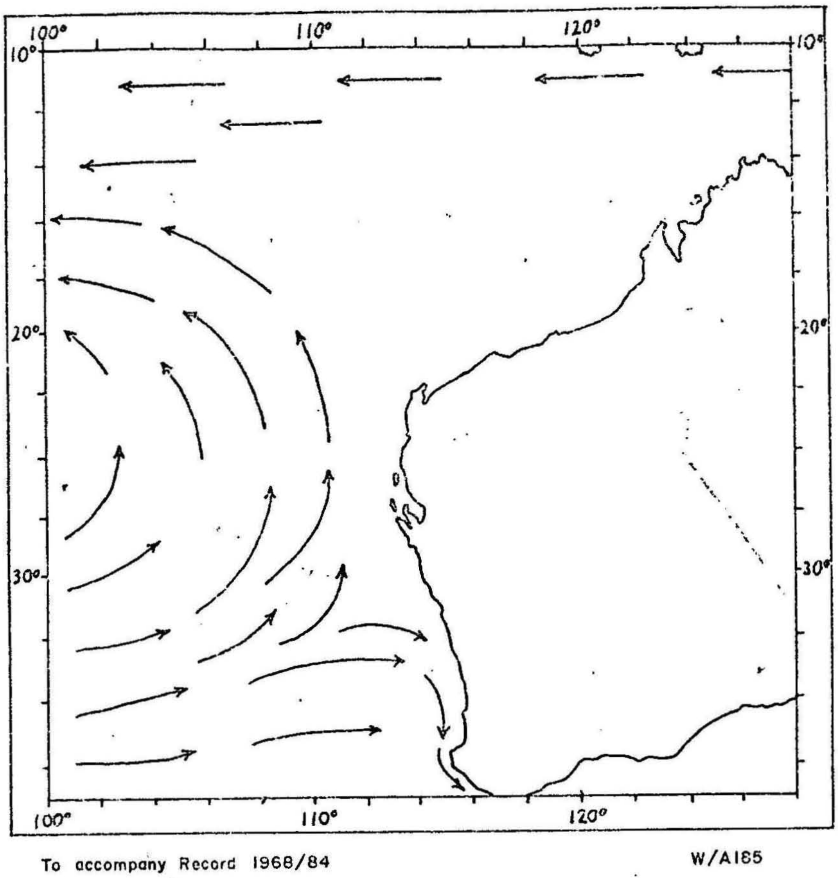


Figure 3: Generalized map of surface currents off Western Australia.

shelf, particularly during the south-east trades, but the data collected by the workers referred to above indicate that any upwelling present is minor. Rochford (1967) in a review of phosphate levels in surface waters of the Indian Ocean, stresses the very low phosphate content of surface waters throughout the year in the south-east Indian Ocean; regions of relative enrichment caused by upwelling or deep mixing in winter are small in area and do not occur east of about 110°E. longitude.

Geology of the bordering land and coastal morphology

There is a marked contrast between the steep rocky coastline with deep inlets and numerous islands of the Kimberley terrain to the north, and the generally low-lying monotonous sandy shores of the Canning Basin to the south.

The western margin of the Kimberley block is formed of Proterozoic rocks of the Kimberley group. These consist of clean-washed quartz sandstones (King Leopold Sandstone, Warton Sandstone, and Pentecost Sandstone), basic volcanics (Carson Volcanics) and siltstones (Elgee Siltstone and facies of the Pentecost Sandstone) intruded by the Hart Dolerite. There is strong folding in the Yampi Peninsula but elsewhere the rocks are largely undeformed.

Except in the Derby area at the head of King Sound, where Permian and Triassic outcrops are found, the coastal fringe of the Canning Basin is formed of Jurassic and Cretaceous rocks almost everywhere hidden by Cainozoic deposits. Twenty-five formations have been named in the Jurassic and Cretaceous and all of these, with the exception of the Poondano Formation and the Cronin Formation, are marine or paralic (Veevers and Wells, 1961). They were deposited in a shallow sea and a single transgressive and regressive cycle can be distinguished. What little sediment there is now being supplied to the Rowley Shelf from the Canning Basin must mostly come from the Cainozoic deposits of the coastal plain. These consist of Tertiary sandstones and conglomerates and Quaternary calcareous rocks.

Previous Investigations

The marine geology of the Timor Sea and Sahul Shelf to the north-east has been described by Van Andel and Veevers (1967). The sediments of that area have many similarities with those described in the present paper, but the morphology of the Sahul Shelf is in general more complex than that of the shelf to the south-west. There is no published account of the sediments of the area under review, but some information of uneven quality is provided by the bottom sediment notations on the Admiralty and Australian charts. Morphological descriptions of the shelf and structural interpretations have been published by Fairbridge (1953), Carrigy and Fairbridge (1954) and Boutakoff (1963); some of their conclusions were based on chart data which have subsequently been found to be incorrect. More recent structural and morphological interpretations have been published by Veevers (1967) and Phipps (1967).

Geophysical surveys in connection with petroleum exploration offshore have provided some evidence on the structure of the north-west shelf. As yet it is largely untested by drilling. Burmah Oil Company's Ashmore Reef well, just to the north of the area, was plugged and abandoned in March, 1968. Drilling is in progress at the time of writing off Port Hedland (Legendre) far to the south-west. Information is not yet available from either well. The geophysical surveys carried out have provided aeromagnetic data, for Woodside (Lakes Entrance) Oil Co. 1964, and marine seismic data, several surveys for Burmah Oil Co. of Australia Ltd since 1965. A marine geophysical programme to be carried out under contract for the B.M.R. will carry out seismic profiling, gravity, and total magnetic intensity measurements over the area described in this report.

EQUIPMENT AND TECHNIQUES

Positioning

No radar or radio aids to navigation were carried in the charter vessel and positioning was achieved by conventional astronomical navigation, land sights and dead reckoning. Clear skies throughout the survey almost always allowed good star and planet fixes to be obtained at dawn and dusk, as well as sun sights during daylight hours. However, as the noon altitude of the sun in these latitudes in the early summer is close to 90°, and it azimuth close to due east in the forenoon and due west in the afternoon, sun sights could often be relied upon for position lines only.

Comparison with the detailed soundings charts of the R.A.N.'s hydrographic surveys and with other evidence, suggests that nearly all station positions are fixed with an error of less than 3 miles.

Sounding and profiling

An echosounding system consisting of an Edgerton Germehausen & Grier Model 228 12 Kcs pinger linked to an Ocean Sonics GDR-T recorder was originally installed; however, the transducer, which was mounted over the side on a rigid strut, was carried away by collision when on passage to the survey area and soundings during the survey was made with a towed 5 Kcs pinger and single-element hydrophone streamer in conjuction with a standard Furuno 850 hull-mounted transducer and bridge recorder. The 5 Kcs pinger achieved very little penetration but the quality of the bottom echo on the record allowed non-depositional pavements to be distinguished fairly readily and to a lesser extent the distinction between coarse- and fine-grained sediments can be made. No sparker profiling was carried out owing to failure of the only multi-element hydrophone streamer available on board.

Sampling Techniques

Surface samples were collected with a Shipek sampler and with dredges of various designs. The Shipek sampler is a spring-actuated device consisting of a cylindrical sampling bucket tripped on contact with the bottom by a weight resting above the bucket. The sampler works well on all except very well-compacted sandy bottoms; up to about 4 kilograms of sample can be recovered and there is quite good protection against washing and loss of fines. A small conical dredge (Fig. 2B) and larger rectangular rock dredges with mouth widths of about 2 feet were also extensively used. A triangular pyramid dredge with a short rigid bridle was designed for use on irregular rocky bottoms, particularly living coral; it recovered good samples and its self-tripping ability when firmly snagged saved much loss of wire.

A gravity corer of about 800 lbs weight with a 10-foot core barrel was carried, but the carbonate sand flooring depositional areas over most of the outer shelf clearly precluded coring. About 5 feet of core were recovered at one station in more argillaceous sediments inshore.

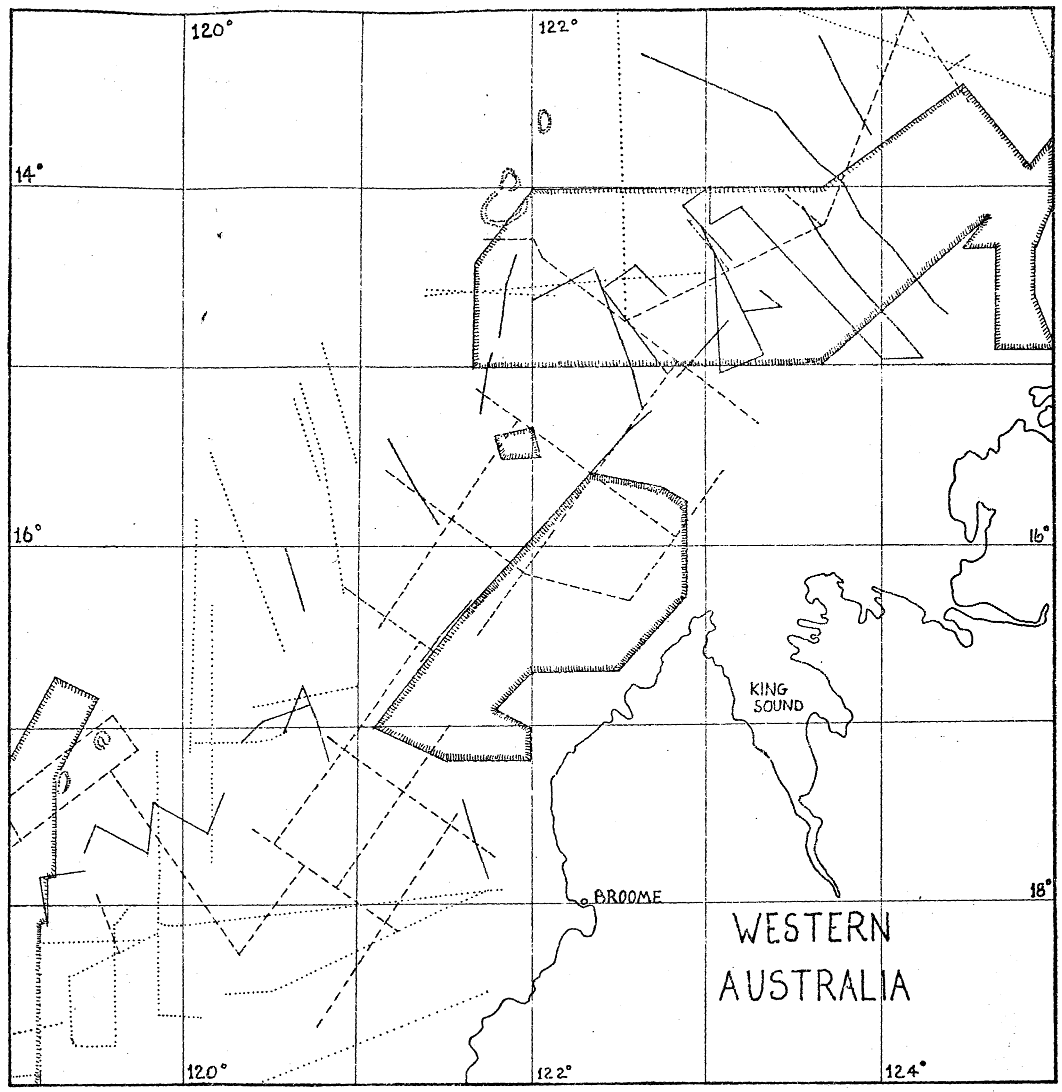
Light sampling equipment was operated from a small diesel-powered winch carrying 3/16-inch diameter wire rope mounted on the boat deck on the starboard side aft. Large dredges and the corer were operated from the fore deck on the starboard side using a boom on the main mast. The forward winch, adapted from a diesel tractor, carried 3000 feet of $\frac{3}{8}$-inch diameter wire rope.

Underwater Photography

An E.G. & G. Model 205 underwater camera and a Model 206 light source were carried. The shutter opening and synchronized flash were triggered by a tilt switch operated by a weight slung 10 feet below the supporting frame. This arrangement gave a field of view of about 50 square feet (Fig. 8).

SUBMARINE MORPHOLOGY AND STRUCTURE

The sources from which the bathymetric chart (Plate 1) was compiled are summarized in Figure 4. Correlation between the various sources, where they overlap, is often poor. Contours shown by broken lines are derived from quite widely spaced lines of soundings supplemented by the scattered soundings shown on Admiralty Charts Nos. 1047, 1048 and 1207; they must be regarded as approximate.



To accompany Record 1968/84

W/A 186

Figure 4: Sources of bathymetric data additional to soundings on published Australian and British Admiralty Charts.
Hachures: areas of detailed hydrographic surveys by the R.A.N.
Full lines: Kos II cruise tracks.
Broken lines: lines of soundings, oil company surveys.
Dotted lines: lines of soundings taken from Oceanic Soundings Sheets 318 and 319 prepared by the Hydrographic Office, R.A.N., from miscellaneous sources.

Shelf edge and continental slope

A study of the contour spacing on Plate 1 shows that the break in slope at the outer edge of the shelf is quite sharply defined at a depth of 120 metres in the region of Browse Island (see cross section 2, Plate 2, and Figure 5). Moving south-westwards the break shallows to 100 metres inshore from Scott Reef (sections 3 and 4) and possibly shallows to as little as 60 metres west of Cape Leveque. In this area, however, detailed soundings are lacking. Continuing south-westwards, the break deepens again to about 120 metres and becomes less sharply defined. In the far north-east also, in the Heywood Shoal area, the shelf edge is not well defined and lies at about 120 metres depth.

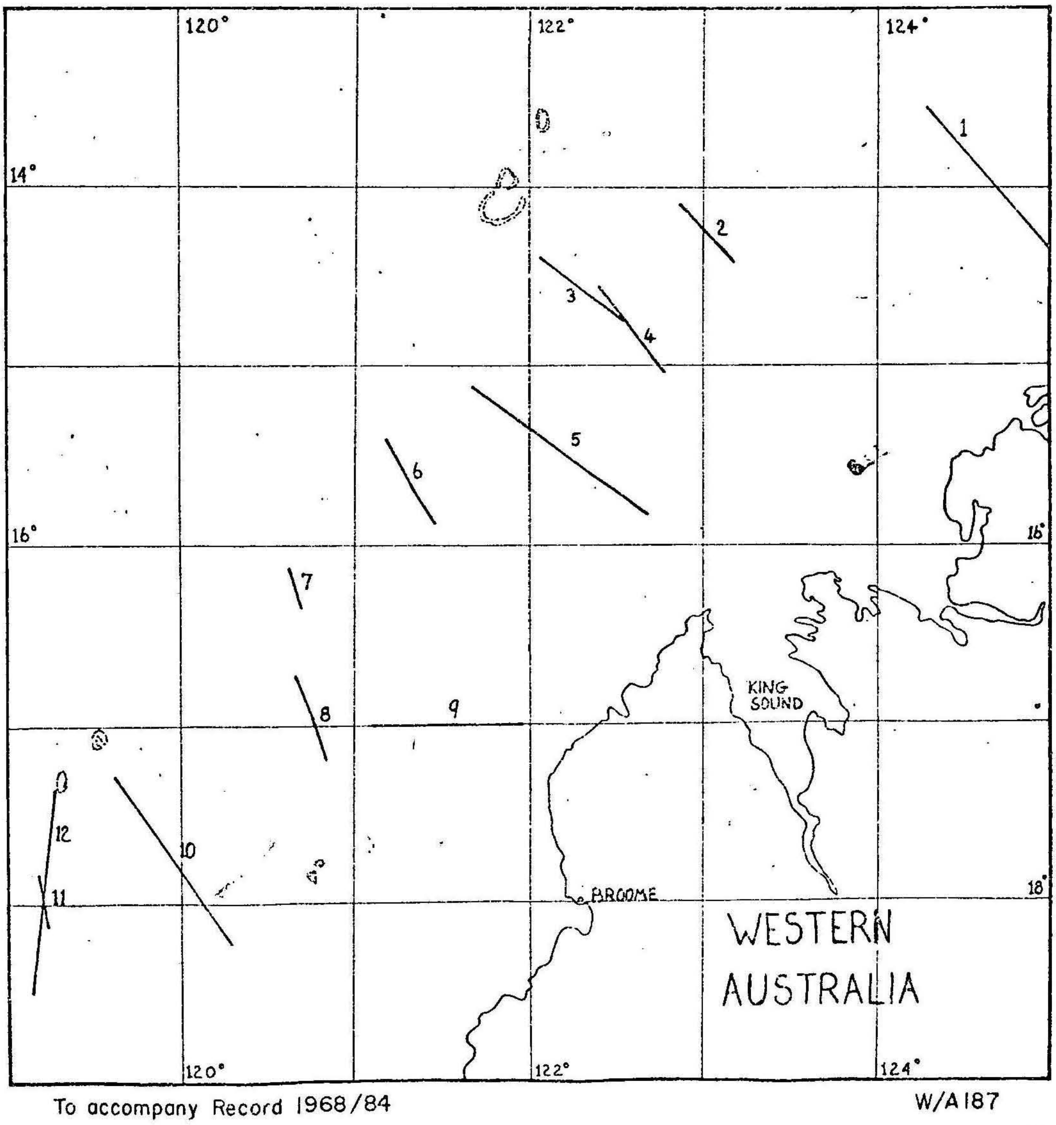


Figure 5: Location of cross sections shown in Plate 2.

Several of the cross sections shown in Plate 2 cut the shelf edge; the profile across the upper part of the continental slope is usually concave but flattens out 10 or 20 metres below the shelf edge which it meets in a gentle, convex curve (sections 2, 3, 6, 11).

There is no reason to follow Fairbridge (1953) in placing the shelf edge at 550 metres (300 fathoms). Van Andel and Veevers (1967) record that there is no regional break in slope at this depth in the Timor Sea and the same is true of the area under review. None of the B.M.R.'s sampling or sounding lines extended to this depth, but profiles constructed from the R.A.N. Oceanic Soundings sheets in the Scott Reef - Rowley Shoals area show that from the floor of the North Australian Basin at 5000 to 6000 metres the rise commences steeply (about 10°) and flattens off as the continental shelf is approached giving a markedly convex cross section. In detail the sections show quite strong irregularities and reversals of slope are common to all. The wide spacing of the lines of soundings, and in many cases their unfavourable orientation, does not allow the ridges and troughs occurring in different sections across the slope to be correlated, but it appears that they are linear features parallel to the continental margin.

Veevers (1967) has suggested that the reefs rising from near the top of the present day continental slope (Rowley Shoals, Scott Reef, Seringapatam Reef) originated as shelf-edge reefs during the Tertiary and that as the continental margin subsided in the later Cainozoic, their upward growth kept pace with the subsidence. The Rowley Shoals rise from about 400 metres, and Scott Reef and Seringapatam Reef from about 500 metres. Small drowned reefs were noted at shallower depths on the upper slope at other places, as for example along section 11 where they occur at between 220 and 250 metres. Browse Island and Echuca Shoal are examples of living reefs rising from very close to the top of the present day slope in depths of about 150 metres and 130 metres respectively. It is probable that drowned reefs are more common than the profiles illustrated here suggest, because many of the latter were constructed from sounding lines with spot depths too widely spaced to detect small, steep sided banks.

A single example of a submarine canyon was noted at about 16°45'S., 120°40'E.; this relatively small and shallow structure has a width of 1 mile along the line it was cut by the ship's track and a depth of 50 metres (see section 8). A smaller trough crossed by the same section near the top of the slope at a depth of 150 metres could be the same canyon.

Abrupt scarp features on the continental slope, resulting from slumping of poorly consolidated sediments, were discovered at two localities, 16°20'S., 120°40'E., and 17°35'S., 120°05'E. In both cases the faults run approximately parallel to the edge of the shelf and well marked troughs run along the foot of the fault scarps. The floor of the troughs are obscured on the echo-sounding records owing to side echos from the walls. The height of the scarp of the northern fault is about 100 metres (see section 7); the southern fault is smaller with a scarp height probably little more than 20 metres.

Middle and outer shelf

There is no evidence in this area of the series of terraces which are a common feature of the continental shelves of other parts of Australia and elsewhere in the world (Phipps, 1967). These terraces, which are erosional features related to still-stands during the post-glacial rise in sea level, might be revealed by careful study of more detailed bathymetric data than are at present available, but it is likely that on the middle and outer shelf they are largely obscured by irregular reef development.

Quite a common feature is the presence of a low bank or a series of ridges along the outermost edge of the shelf, sometimes with a complementary trough on the landward side. The best example of these features is revealed by the R.A.N. detailed soundings of the approaches to Port Hedland (section 12, Plate 2). They also appear, though much less well developed, in sections 3 and 5. Cross sections 2 and 4 show smaller steep-sided banks at, or close to, the shelf edge; these are probably reefs and have no structural significance.

Small scale morphological features on the shelf revealed by the B.M.R. echo-sounding and finger records to some extent reflect the current regime of sediment erosion, transport and deposition; it is not possible, however, to distinguish depositional from non-depositional areas by morphology alone. In zones of transport, sand waves with a height of about 4 metres and wave length of up to 300 metres sometimes indicate direction of movement by their asymmetry. Smooth flat surfaces may be depositional, but wide areas with a similar profile are in many cases non-depositional pavements formed of more or less indurated accumulations of dead shells.

Regional structure

A compilation of aeromagnetic data by Veevers (1967) indicates the presence of a trough in the magnetic basement running close to, but generally seaward of, the shelf edge from the Rowley Shoals to the Sahul Shelf. This structure, named the Cartier Furrow by Veevers, is not reflected by the existing sea bed morphology except in so far as it runs broadly parallel to the shelf edge. Likewise, although it is tempting to relate the Leveque Rise basement high to the bathymetric high running westwards from Adele

Island to Lynher Reef (recently expunged from the charts as an R.A.N. survey has shown a least depth in this area of about 30 metres), a complementary trough in the magnetic basement just to the south lies on the same bathymetric high. That the general line of the Leveque Rise is an area of Quaternary uplift is, however, strongly suggested by the shallowing of the shelf edge which stands some 60 metres higher here than elsewhere in the area. The two fault structures noted on the upper continental slope both lie on the southern flank of the Leveque Rise and provide further evidence of recent tectonic activity.

SEDIMENTS

Introduction and laboratory techniques

One hundred and sixty-three stations were occupied and bottom samples were recovered at all except six of these. Failure to retrieve a sample occurred when smooth rock pavement formed the bottom except in two cases when gear failure was responsible for the non-recovery of samples. Station distribution is shown in Figure 6, and sample data are summarized in the Appendix.

Material recovered with a grab or dredge was hand mixed; a small fraction (about 50g) was sealed in a phial as a reference sample, about 1 Kg was retained for later laboratory treatment, and 100 to 200g was stained and preserved in alcohol for study of the foraminifera.

Laboratory treatment of the large subsample consisted of textural analysis, determination of total carbonate and P_2O_5, and petrographic study by means of binocular microscope examination of whole grains and ordinary thin section optical mineralogy. Salt was removed from the samples before analysis by washing in fresh water and drying at 80°C.

For the reasons given in the section on the texture of the sediments, mechanical analyses were not carried out to completion, the -63 micron fraction being grouped as silt and clay, and samples with a high clay content requiring wet sieving and pipetting have not yet been analysed. Samples were split and a subsample of about 50 g weight was passed through a nest of seven sieves on a mechanical shaker covering the range 4 mm to 63 microns at one-phi intervals. It is intended to repeat these analyses using a sedimentation tube for the sand fraction and the standard pipette method for the fine fraction when samples from the whole NW shelf province have been collected.

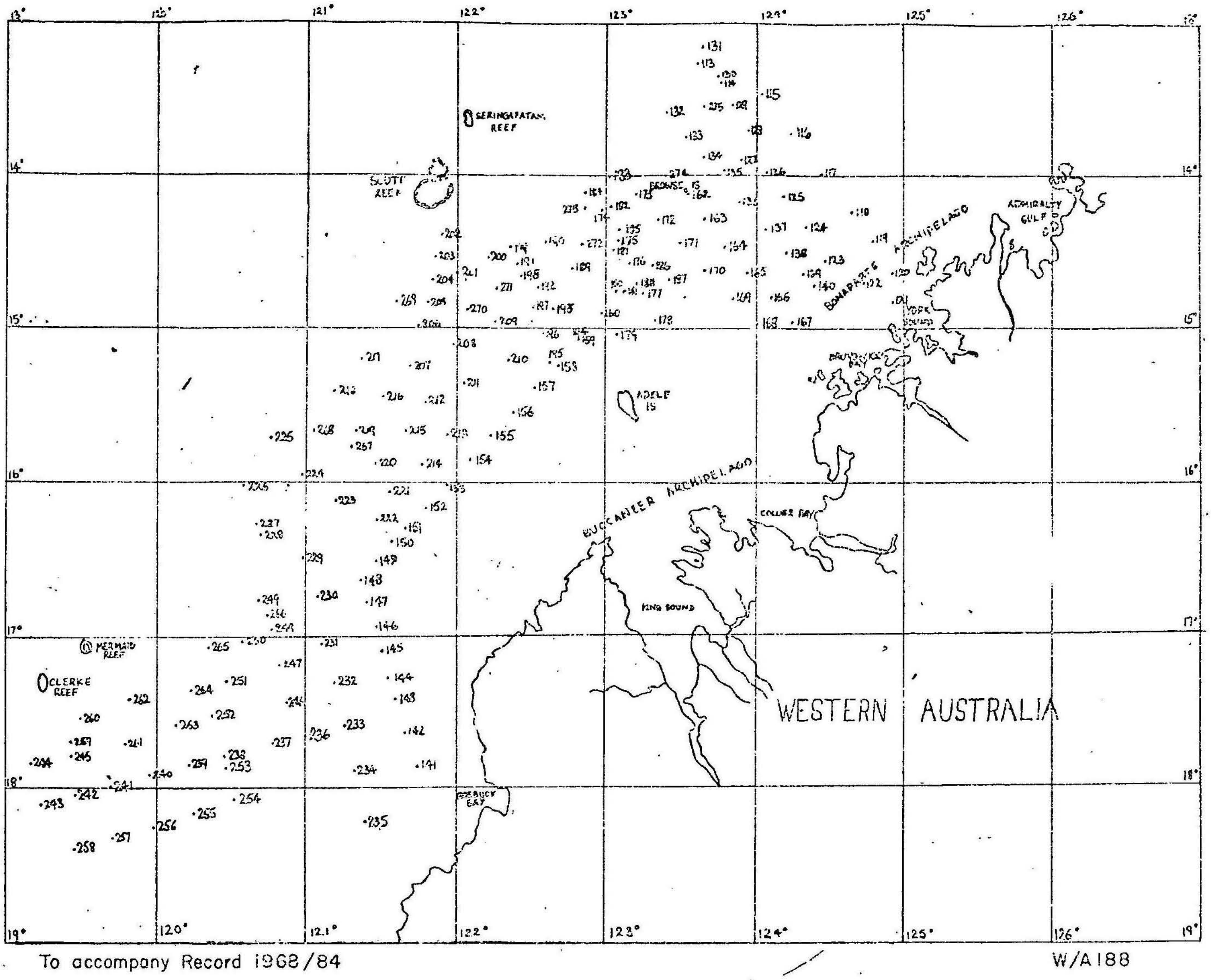


Figure 6: Location of sample stations

Total carbonate was determined by measurement of the carbon dioxide evolved when the sample digested in 2-N hydrochloric acid, using the apparatus described by Hülsemann (1967). It was found that the use of mercury in the gas barette and reservoir introduced errors owing to the difficulty in equalizing the liquid levels exactly, and a liquid with a lower specific gravity, in this case kerosene, was employed.

Phosphate was determined by digesting a measured quantity of the finely ground sample in acidified ammonium molybdate - ammonium metavanadate solution and colorimetric comparison of the resulting precipitate against a set of standards (Shapiro, 1952).

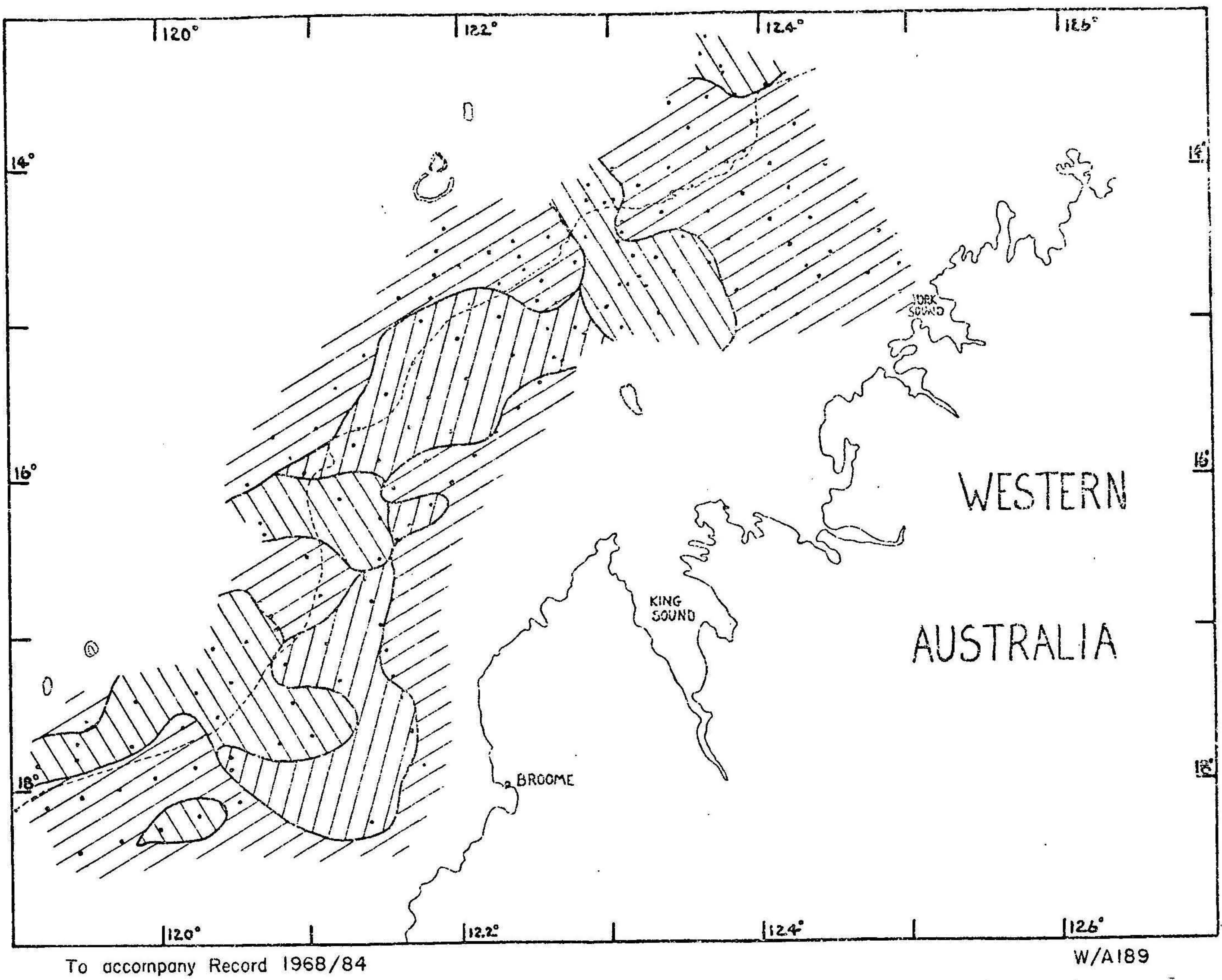


Figure 7: Textures of surface sediments.
ENE - WSW pattern: silty and clayey sediments.
NW - SE pattern: medium- and coarse-grained calcarenites dominant.
NNE - WSW pattern: poorly sorted calcarenites.

A

B

Figure 8A: Station 113, depth 282 metres. Pavement and platy slabs of limestone almost bare of loose sediment. Trip weight shackle is about 12 inches long.

Figure 8B: Station 206, depth 132 metres. Flat floor dominantly composed of coarse relict shell material.

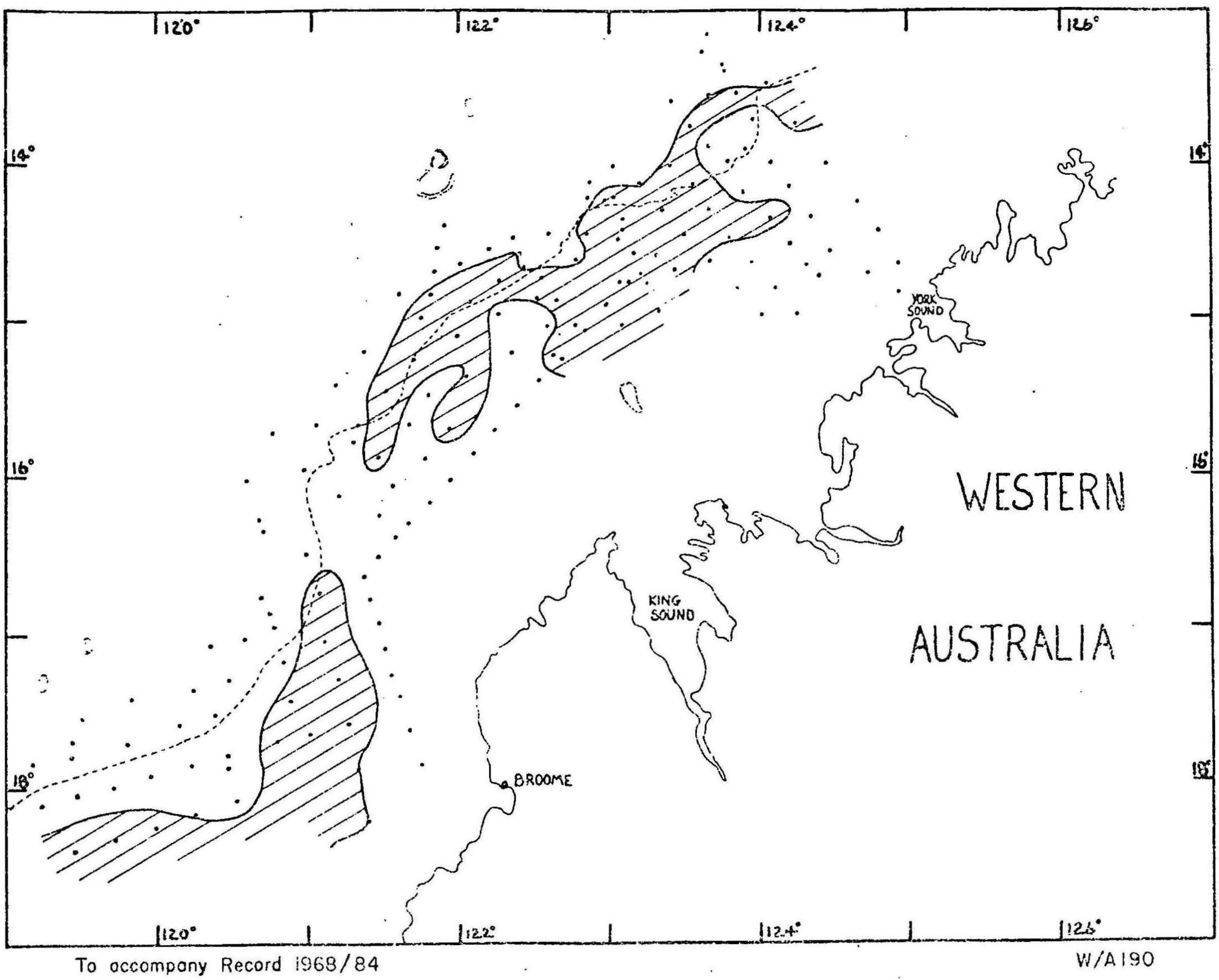


Figure 9: Distribution of oolites and oolitic sediments.

Texture

The somewhat disordered relationship of the various textural types of the shelf sediments of the Sahul Sheld, described by Van Andel and Veevers (1967), is much more strongly marked in the area under review (Fig. 7). Large areas of the middle and outer shelf are zones of sediment transport rather than deposition and minor irregularities on the sea floor and other factors influencing the local current regime are important in controlling the textures of the sediments. Although the picture of grain size distribution is confused, Figure 7 shows that the sediments with a significant fine-grained fraction are mainly confined to an inshore zone and to a belt beyond the shelf edge. In both cases the fine fraction is mostly terrigenous in origin, but the deep water silty and clayey sediments include a variable proportion of pelagic foraminifera and silt-sized carbonate which fall into the sub-sandsize grade.

Figure 7 shows that a large part of the shelf between about 50 metres depth and the shelf edge at 120 to 160 metres is floored by poorly sorted sediments or by sediments in which the medium and coarse sand fractions are dominant. This is also the area where oolitic sediments are common (Fig. 9); it is essentially a current swept, high energy environment in which, apart from the authigenic carbonate forming the oolites and minor glauconite, there is little or no sedimentation in progress. Extensive areas are floored by coarse shell debris, chiefly calcareous worm tubes and dead coral fragments, which represent littoral and sub-littoral deposits formed during the post-Pleistocene rise in sea level and which have not been covered by later deposits (Fig. 8). The ill-sorted nature of much of the material analysed to some extent reflects the sampling technique and gives a distorted picture of sea-floor conditions. Much of the relict biogenic carbonate in these areas is more or less cemented to form a hard pavement and prolonged and often repeated dredging was necessary to obtain a sample; the loose sediment collected in the dredge at many stations may therefore have been recovered from a number of quite widely separated pockets of sediments in an area largely swept clean of sand and mud.

Oolites

As noted above oolites and oolitic calcarenites are confined to the middle and outer part of the continental shelf (Fig. 9). There is little evidence to explain the break in continuity of the oolite zone along the outer shelf in the region of 16°S.; density of sample stations is very low in this area and the break may not in fact exist. However, Figures 9 and 10 indicate quite a strong negative correlation between oolite occurrence and occurrence of a significant terrigenous component (as evidenced by relatively

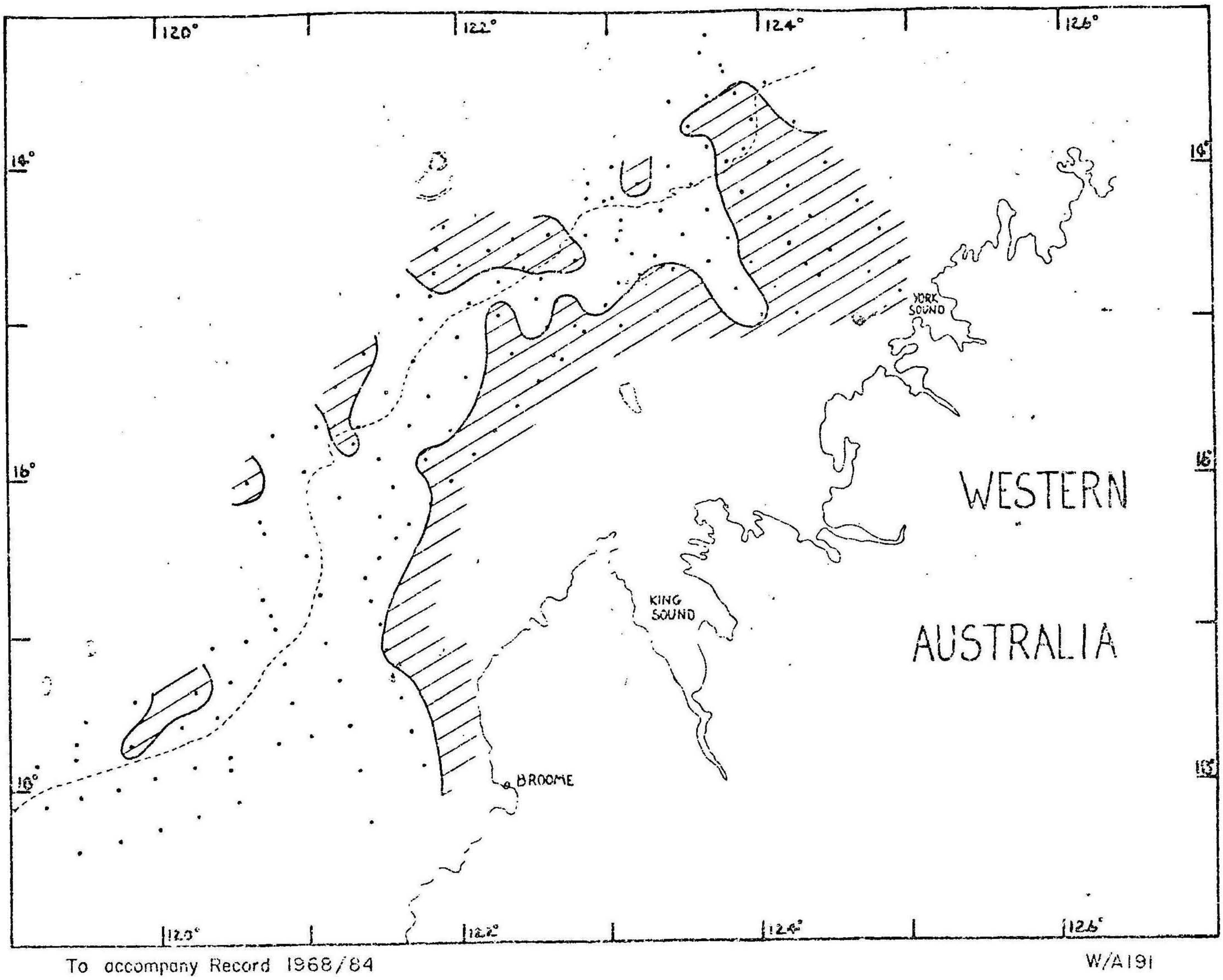
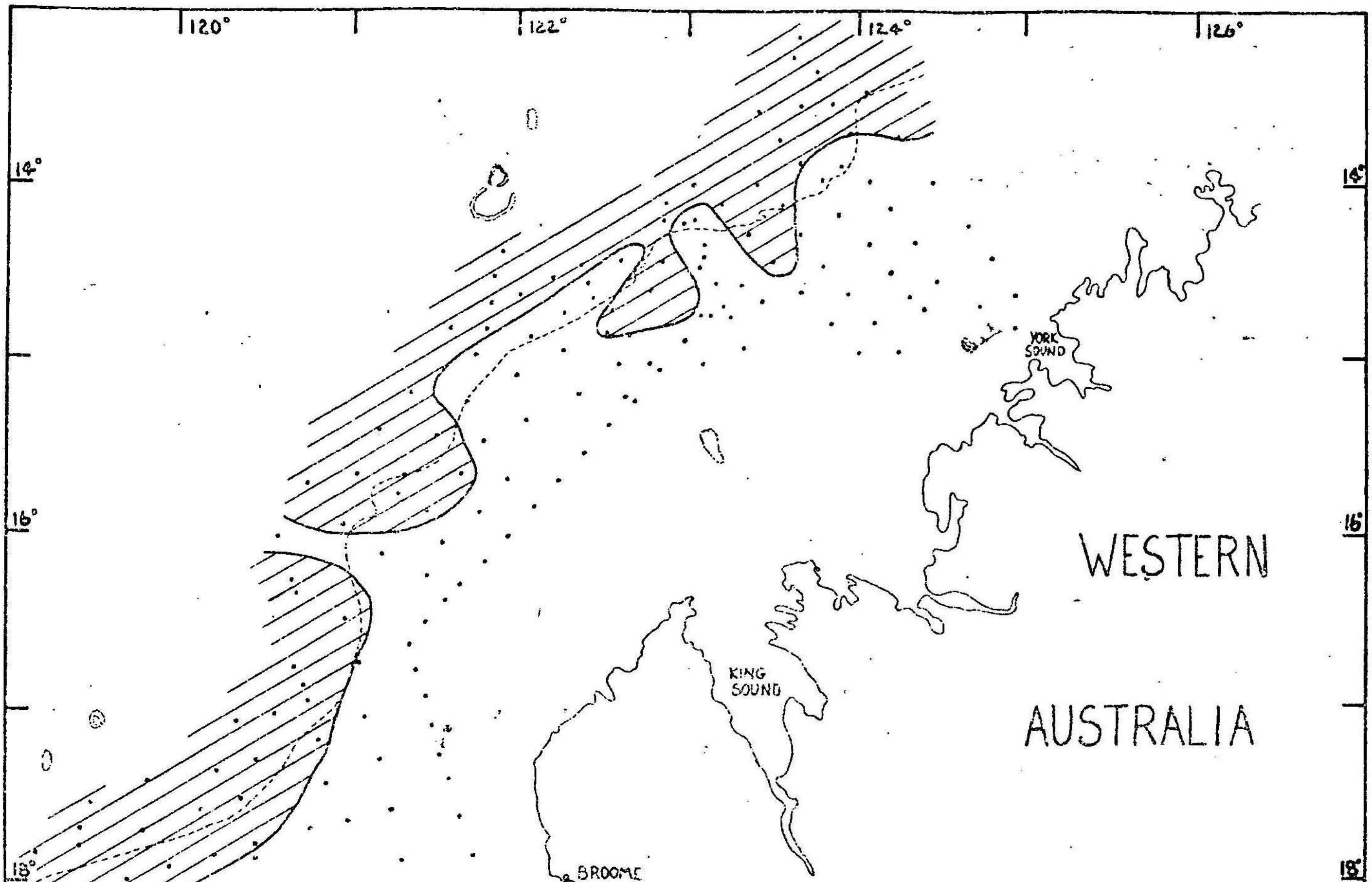


Figure 10: Distribution of sediments containing less than 85 percent carbonate (shaded areas).



<u>Figure 11</u>: Distribution of sediments containing a significant proportion of planktonic foraminifera.

low carbonate content) and it is possible that in this area, as well as in the area south-east of Clerke Reef, south-east of Scott Reef, and in the region of 14°S., environmental energy is low enough to allow deposition of terrigenous sediment and is too low to favour oolite formation.

Thin sections indicate that the oolites nearly all consist mainly of structureless micrite with only a very thin envelope of regularly orientated microcrystalline carbonate; both radial and tangental orientation of carbonate crystals occur. Whole grains under the binocular microscope exhibit the highly polished glassy surface lustre typical of oolites.

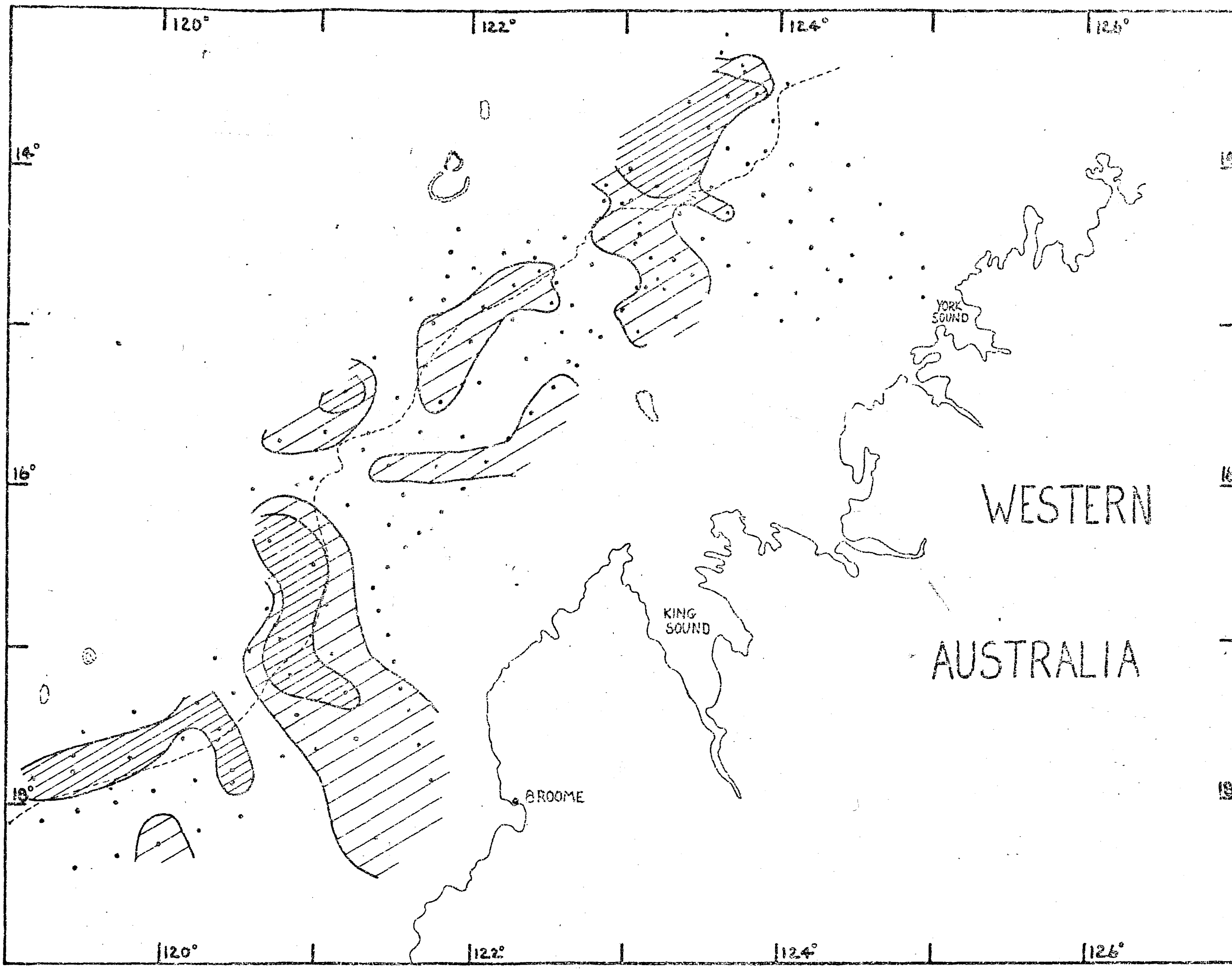
Carbonate, phosphate and glauconite

In contrast to the Sahul Shelf and Joseph Bonaparte Gulf, where quite large areas are floored by sediments relatively low in carbonate, only four samples in this area contained less than 50 percent carbonate. Three of these came from the approaches to York Sound and the fourth came from due west of Adele Island. In only one area, to the south-east of the Rowley Shoals in water depths of 240 to 300 metres, is the proportion of non-carbonate authigenic material, in this case glauconite, high enough to influence the pattern shown in Figure 10. As in the Sahul Shelf samples, there is a good negative correlation between silt and clay content and carbonate content complicated to some extent by the occurrence of abundant silt-sized planktonic foraminifera and micritic carbonate in some of the deeper water areas (Fig. 11). The fine fraction is mainly of terrigenous origin and therefore the low carbonate areas indicated in Figure 10 are those where the deposition of terrigenous material is allowed by the environmental energy pattern.

The abundance of planktonic foraminifera in some of the relatively shallow water shelf sediments (Fig. 11) is well marked and provides further evidence of very slow sedimentation.

Glauconite is a widespread but minor constituent of the sediments. It forms discrete grains, which take the form of ellipsoidal pellets, irregular nobbly grains, or casts of gastropod and foraminifera chambers, or it occurs in cavities in shells where it may occupy the whole chamber, or more commonly form part of the infilling mixed with yellow and brown clay material and micritic carbonate.

Traces of phosphate occur in the sediments of the outer shelf over quite wide areas (Fig. 12), but values are uniformly low. Ten percent P_2O_5 was recorded at two stations, 9 percent at three stations, 3 to 7 percent at 11 stations and trace to 2 percent at 46 stations. These values refer to the fine fraction of the sediment which also includes shell material and concretionary carbonate. The P_2O_5 content of the bulked material would not exceed half the values quoted. The phosphate occurs as relatively pure collophane pellets and angular fragments up to 3 mm in diameter, and as more or



To accompany Record 1968/84 W/A193

Figure 12: Distribution of phosphatic sediments.
Open pattern: trace to 2 percent P_2O_5.
Close pattern: 2 to 10 percent P_2O_5.

less impure casts and infillings of gastropods, foraminifera and lamelli branchs. It also occurs as highly impure angular fragments of very fine-grained lithic material consisting of yellowish brown indeterminate clay, microcrystalline carbonate, small shell fragments, and collophane. Slaty fragments 10 mm across and 1 mm thick of this impure phosphatic material have been recovered and it seems that it may represent a thin skin or crust in process of formation locally at the sediment-water interface. Partially phosphatized shell fragments and serpulid tubes several centimetres in length were also noted.

Study of the impure phosphatic material in thin section is unrewarding owing to the intimate mixture and fine state of division of the carbonate, collophane, and clay material components. However under the binocular microscope whole grains with a significant phosphate content have a very characteristic waxy surface lustre and can usually be distinguished fairly readily from the other brown and black grains present.

The five samples with P_2O_5 values of 9 to 10 percent, with one exception, were recovered from well below the shelf edge break in slope in water depths of 247 to 329 metres. The exception is station 253 which is located on the flank of a low ridge close to the shelf edge in 121 metres of water. The P_2O_5 isopleths shown in Figure 12 are to some extent open on the seaward side, particularly between 13° and 14°S., and 15° and 17°S., but sufficient samples were collected from deeper water to suggest that phosphate values decrease down the continental slope below about 300 metres depth.

It is emphasized that the phosphate values quoted above, and those given in the Appendix and indicated in Figure 12, refer to the fine fraction of the superficial sediment only. Also the Shapiro method for phosphate determinations is not particularly reliable for low P_2O_5 concentrations, particularly in the presence of abundant carbonate.

REFERENCES

BOUTAKOFF, N., 1963 - Geology of the offshore areas of north-western Australia. APEA J. 7(2), 44-49.

CARRIGY, M.A., and FAIRBRIDGE, R.W., 1954 - Recent sedimentation, physiography and structure of the continental shelves of Western Australia. J. Roy. Soc. W. Aust., 38, 65-95.

FAIRBRIDGE, R.W., 1953 - The Sahul Shelf, northern Australia; its structure and geological relationships. J. Roy. Soc. W. Aust., 37, 1-33.

HAMON, B.V., 1965 - Geostrophic currents in the south-eastern Indian Ocean. Aust. J. mar. freshw. Res., 16(3), 255-271.

HULSEMANN, J., 1967 - The continental margin off the Atlantic coast of the United States: carbonate in sediments, Nova Scotia to Hudson Canyon. Sedimentology 8, 121-145.

PHIPPS, C.V.G., 1967 - The character and evolution of the Australian continental shelf. APEA J., 7(2), 44-49.

ROCHFORD, D.J., 1962 - Hydrology of the Indian Ocean II. The surface waters of the south-east Indian Ocean and the Arafura Sea in spring and summer. Aust. J. mar. freshw. Res., 13(3), 226-251.

ROCHFORD, D.J., 1967 - The phosphate levels of the major surface currents of the Indian Ocean. Aust. J. mar. freshw. Res. 18(1), 1-22.

SHAPIRO, L., 1952 - Simple field method for the determination of phosphate in phosphate rocks. Am. Mineralogist, 37, 341-342.

TRANTER, D.J., 1962 - Zooplankton distribution in Australasian waters. Aust. J. mar. freshw. Res. 13(2), 106-142.

VAN ANDEL, Tj. H. and VEEVERS, J.J., 1967 - Morphology and sediments of the Timor Sea. Bur. Miner. Resour. Aust. Bull., 83.

VEEVERS, J.J., 1967 - The Phanerozoic geological history of northwest Australia. J. geol. Soc. Aust., 14(2), 253-271.

VEEVERS, J.J., and WELLS, A.T., 1961 - The geology of the Canning Basin, Western Australia. Bur. Miner. Resour. Aust. Bull., 60.

WYRTKI, K., 1961 - Naga Report Vol. 2. Scripps Institution of Oceanography, University of California.

WYRTKI, K., 1962 - Upwelling in the region between Java and Australia during the south-east monsoon. Aust. J. mar. freshw. Res., 13(3), 217-225.

APPENDIX

NOTES: Times are all GMT + 8 hours. Depths are in metres uncorrected for tidal variations. See text for details of positioning accuracy and for the basis for the carbonate and phosphate values given. Sample descriptions are based on macroscopic and binocular microscope examination and textural terms are not derived from complete mechanical analyses; in particular the terms calcilutite and clay are loosely used to cover all sub-sandsize material and although this is mainly in the clay fraction some silt grade material may be included. The adjective foraminiferal is used to describe samples in which pelagic foraminifera are dominant. An asterisk indicates that limestone pavement, or loose or cemented coarse shelly rubble, probably occurs at the station; unconsolidated sediment recovered at these stations occurs as a very thin veneer or lies in pockets on this surface.

Station No. (K67-)	Date & Time (1967)	Lat.	Long.	Depth (m)	Carbonate %	P_2O_5 %	Sample description and Remarks
113	22/10 0550	13°16'S	123°37'E	282	>90	1	*Grey and brown cavernous limestone. No unconsolidated sediment
114	22/10 1350	13°23'S	123°46'E	192	>90	2	*Grey oolitic and pelletal limestone. No unconsolidated sediment
115	22/10 1805	13°28'S	124°03'E	22	>90	NIL	*Living coral, coarse shell debris. Heywood Shoal
116	22/10 2300	13°43'S	124°14'E	112	87	NIL	Grey-green, shelly, clayey calcarenite
117	23/10 0300	13°59'S	124°27'E	82	66	NIL	Grey-green, shelly, very clayey calcarenite
118	23/10 0700	14°14'S	124°39'E	68	67	NIL	Grey-green, shelly, very clayey calcarenite
119	23/10 0926	14°25'S	124°47'E	51	78	NIL	Grey-green, shelly, very clayey calcarenite
120	23/10 1150	14°38'S	124°56'E	44	49	NIL	Grey-green, shelly, very clayey, calcareous, silt
121	23/10 1348	14°49'S	124°56'E	44	48	NIL	Grey-green, shelly, clayey, calcareous silt
122	23/10 1555	14°42'S	124°43'E	57	47	NIL	Grey-green, shelly, calcareous clay
123	23/10 2000	14°33'S	124°28'E	60	62	NIL	Grey-green, very shelly, calcilutite
124	23/10 2300	14°20'S	124°20'E	80	72	NIL	Grey-green, shelly, calcilutite
125	24/10 0300	14°08'S	124°11'E	99	72	NIL	Grey-green, shelly, calcilutite
126	24/10 0630	13°59'S	124°05'E	97	70	NIL	Grey-green, calcilutite
127	24/10 -	13°54'S	123°54'E	18	-	NIL	*Living fern corals and some coarse shell debris. Echuca Shoal
128	24/10 2000	13°42'S	123°57'E	144	70	NIL	Grey-green, shelly calcilutite
129	24/10 2300	13°32'S	123°51'E	181	72	6	Grey-brown, coarse, shelly, oolitic calcarenite
130	25/10 0300	13°21'S	123°45'E	196	99	TR	Grey-brown, foraminiferal calcarenite
131	25/10 0630	13°09'S	123°39'E	280	-	NIL	Grey-brown, foraminiferal calcarenite
132	26/10 2330	13°35'S	123°24'E	325	85	-	Light brown, foraminiferal calcarenite
133	27/10 0300	13°45'S	123°32'E	261	66	9	Grey-green, slightly clayey, foraminiferal oolite
134	27/10 0630	13°53'S	123°39'E	199	87	NIL	Grey-green, clayey, shelly calcarenite
135	27/10 1005	14°02'S	123°47'E	176	80	NIL	Grey-green, clayey, shelly calcarenite
136	27/10 1502	14°10'S	123°54'E	122	70	NIL	Grey-green, shelly calcilutite
137	27/10 1915	14°21'S	124°04'E	115	80	NIL	Grey-green, very clayey, shelly calcarenite
138	27/10 2300	14°30'S	124°12'E	90	70	NIL	Grey-green, very clayey, shelly calcarenite
139	28/10 0230	14°38'S	124°19'E	71	74	NIL	Grey-green, shelly calcilute

Station No. (K67-)	Date & Time (1967)		Lat.	Long.	Depth (m)	Carbonate %	P_2O_5 %	Sample description and Remarks
140	28/10	0500	14°43'S	124°24'E	64	72	NIL	Grey-green, shelly calcilutite
141	6/11	1130	17°51'S	121°45'E	53	86	2	Grey-green, clayey, shelly calcarenite
142	6/11	1500	17°37'S	121°40'E	57	90	1	Light brown, coarse, shelly calcarenite
143	6/11	1800	17°25'S	121°36'E	55	92	TR	Grey-brown, coarse, slightly clayey, shelly calcarenite
144	6/11	2100	17°16'S	121°33'E	60	85	TR	Grey-green, clayey, shelly calcarenite
145	7/11	0000	17°06'S	121°30'E	57	84	NIL	Grey-green, shelly calcarenite
146	7/11	0300	16°57'S	121°27'E	42	89	NIL	Grey-brown, shelly calcarenite
147	7/11	0600	16°48'S	121°24'E	40	98	NIL	*Grey-brown, shelly calcarenite
148	7/11	0830	16°40'S	121°23'E	42	90	NIL	Grey-brown, slightly clayey, shelly calcarenite
149	7/11	1145	16°32'S	121°29'E	51	95	NIL	Light brown, coarse, shelly calcarenite
150	7/11	1450	16°25'S	121°35'E	55	93	NIL	*Light brown, coarse, shelly calcarenite
151	7/11	1745	16°18'S	121°40'E	69	92	NIL	Light brown, shelly calcarenite
152	7/11	2045	16°10'S	121°48'E	64	86	NIL	Brown, coarse, shelly calcarenite
153	7/11	2345	16°01'S	121°57'E	60	75	NIL	Grey-green, clayey shelly calcarenite
154	8/11	0245	15°51'S	122°06'E	53	76	TR	Grey-green, slightly clayey, shelly calcarenite
155	8/11	0545	15°42'S	122°14'E	53	60	NIL	Grey-green, clayey, shelly calcarenite
156	8/11	0845	15°33'S	122°23'E	80	42	1	Brown-green, clayey, shelly, calcareous sand
157	8/11	1215	15°23'S	122°32'E	75	61	1	*Brown-green, clayey, shelly calcarenite
158	8/11	1545	15°13'S	122°41'E	91	75	NIL	*Brown-green, clayey shelly oolite with cemented lumps of shelly debris
159	8/11	2200	15°04'S	122°50'E	101	68	NIL	Brown-green, clayey shelly, oolitic calcarenite
160	9/11	0115	14°54'S	122°59'E	101	85	TR	Brown, shelly, sandy oolite
161	9/11	0415	14°45'S	123°08'E	95	88	TR	*Brown, slightly clayey, shelly, sandy oolite
162	9/11	1800	14°07'S	123°33'E	128	93	NIL	*Grey-green, clayey, shelly calcarenite
163	9/11	2100	14°17'S	123°40'E	119	92	TR	Grey-green, clayey, shelly, oolitic calcarenite
164	10/11	0000	14°28'S	123°48'E	97	89	NIL	Grey-green, slightly clayey, shelly, oolitic calcarenite
165	10/11	0300	14°38'S	123°57'E	79	81	NIL	Grey-green, very clayey, shelly calcarenite
166	10/11	0600	14°48'S	124°06'E	58	76	NIL	Grey-green, shelly calcilutite
167	10/11	0900	14°57'S	124°15'E	55	64	NIL	Grey-green, shelly, sandy calcilutite
168	10/11	1340	14°58'S	124°01'E	53	88	NIL	Grey-green, clayey, shelly calcarenite
169	10/11	1700	14°48'S	123°51'E	69	89	NIL	Grey-green, clayey shelly calcarenite
170	10/11	2030	14°37'S	123°40'E	80	88	NIL	*Grey-brown, coarse, shelly calcarenite
171	11/11	0000	14°26'S	123°30'E	93	98	NIL	Grey-green, slightly clayey, shelly, oolitic calcarenite
172	11/11	0300	14°17'S	123°21'E	104	88	NIL	*Grey-green slightly clayey, shelly, oolitic calcarenite
173	11/11	0600	14°07'S	123°12'E	256	64	7	*Grey silty and sandy calcilutite
174	11/11	1145	14°13'S	122°59'E	159	90	2	Grey-brown slightly clayey shelly oolite
175	11/11	1600	14°25'S	123°05'E	104	95	TR	*Grey-green, shelly oolitic limestone. No unconsolidated sediment
176	11/11	1833	14°34'S	123°09'E	115	93	TR	Grey-green, slightly clayey, shelly oolite
177	11/11	2130	14°46'S	123°15'E	106	83	1	Brown, coarse, shelly oolitic calcarenite
178	12/11	0030	14°57'S	123°20'E	84	82	TR	*Brown, coarse, shelly, oolitic calcarenite
179	12/11	0420	15°02'S	123°05'E	95	64	NIL	Grey-green, clayey,shelly, oolitic calcarenite
180	12/11	0730	14°46'S	123°04'E	110	86	NIL	*Brown-green, shelly, sandy oolite
181	12/11	1130	14°29'S	123°03'E	124	95	TR	Brown-green shelly, sandy oolite
182	12/11	1530	14°12'S	123°02'E	194	95	1	Brown, shelly oolite
183	12/11	2030	14°01'S	123°02'E	289	87	3	Grey-green, pelletal, foraminiferal calcarenite
184	13/11	0020	14°07'S	122°52'E	256	85	2	Light-brown, shelly,foraminiferal calcarenite
185	13/11	0030	14°21'S	123°05'E	130	93	•	*Light brown, shelly, sandy oolite
186	13/11	0715	14°35'S	123°18'E	113	81	TR	*Dark brown-green shelly sandy oolite. Include coarse dead shell material
187	13/11	0920	14°41'S	123°25'E	110	81	TR	Dark brown-green, shelly, sandy oolite
188	13/11	1225	14°42'S	123°12'E	106	89	TR	Brown-green, shelly, sandy oolite
189	13/11	1710	14°36'S	122°47'E	176	67	NIL	Grey-green, very clayey, shelly calcarenite
190	13/11	2030	14°26'S	122°36'E	229	83	NIL	Pale grey-green, slightly shelly calcilutite
191	13/11	2345	14°34'S	122°25'E	247	84	NIL	Pale grey-green, slightly shelly and oolitic calcilutite
192	14/11	0300	14°44'S	122°33'E	106	92	NIL	Grey-green, clayey, shelly, oolitic calcarenite
193	14/11	0615	14°52'S	122°39'E	102	79	NIL	Grey-green, slightly clayey, very shelly, oolitic calcarenite
194	14/11	0940	15°03'S	122°47'E	102	87	NIL	Dark brown-green very coarse shelly and oolitic calcarenite
195	14/11	1315	15°13'S	122°39'E	91	80	NIL	*Grey-green, nodular, oolitic and shelly calcarenite
196	14/11	1600	15°02'S	122°35'E	88	81	NIL	*Grey-green, nodular, pelletal, shelly calcarenite
197	14/11	2030	14°51'S	122°31'E	95	89	TR	Grey-green, clayey, oolitic, shelly calcarenite
198	14/11	2330	14°39'S	122°26'E	165	64	TR	Grey-green slightly sandy and shelly calcilutite
199	15/11	0130	14°28'S	122°22'E	265	•	NIL	Grey-green, slightly clayey, foraminiferal calcarenite
200	15/11	0430	14°32'S	122°13'E	263	72	NIL	Grey-green, slightly clayey, foraminiferal calcarenite
201	15/11	0800	14°38'S	122°01'E	285	63	NIL	Grey-green, sandy, foraminiferal calcilutite
202	17/11	2000	14°23'S	121°54'E	366	67	NIL	Grey-green, slightly sandy, foraminiferal calcilutite
203	17/11	2400	14°32'S	121°52'E	292	78	NIL	Grey-green, very clayey, foraminiferal calcarenite
204	18/11	0345	14°41'S	121°51'E	265	67	NIL	Grey-green, clayey, foraminiferal calcarenite
205	18/11	0730	14°50'S	121°49'E	230	88	NIL	Light brown, shelly, oolitic calcarenite
206	18/11	1100	14°59'S	121°45'E	132	85	2	*Brown, coarse, shelly, oolitic calcarenite
207	18/11	1530	15°15'S	121°42'E	102	>90	NIL	*Living gastropods and shell debris only
208	18/11	2000	15°06'S	121°59'E	84	95	TR	Brown, shelly, oolitic calcarenite
209	18/11	2335	14°57'S	122°16'E	95	84	NIL	*Brown, shelly, oolitic calcarenite
210	19/11	0440	15°12'S	122°21'E	88	82	NIL	Brown-green, clayey, shelly oolitic calcarenite
211	19/11	0900	15°21'S	122°03'E	91	96	NIL	*Light brown, coarse, shelly, slightly oolitic and clayey calcarenite
212	19/11	1220	15°29'S	121°48'E	44	90	TR	*Light brown, shelly, clayey, slightly oolitic calcarenite
213	19/11	1545	15°42'S	121°57'E	69	93	NIL	*Brown, coarse, shelly, slightly oolitic calcarenite
214	19/11	1900	15°53'S	121°47'E	58	76	TR	Grey-green shelly calcarenite
215	19/11	2220	15°40'S	121°40'E	80	85	NIL	*Grey-brown, shelly, slightly clayey calcarenite
216	20/11	0140	15°27'S	121°31'E	210	90	NIL	Grey-brown, slightly muddy, shelly oolite
217	20/11	0520	15°12'S	121°22'E	329	77	NIL	Light grey-green, shelly calcilutite

Station No. (K67-)	Date & Time (1967)	Lat.	Long.	Depth (m)	Carbonate %	P_2O_5 %	Sample description and Remarks
218	20/11 0900	15°24'S	121°11'E	285	78	3	*Grey-green, slightly clayey, foraminiferal calcarenite
219	20/11 1345	15°40'S	121°20'E	106	86	NIL	*Coarse corroded shell material
220	20/11 1732	15°53'S	121°28'E	95	92	TR	*Grey-brown, shelly, quartzose oolite
221	20/11 2017	16°04'S	121°34'E	62	-	NIL	*Living fern coral only
222	20/11 2345	16°16'S	121°24'E	67	93	NIL	Light brown, coarse, shelly calcarenite
223	21/11 0240	16°07'S	121°12'E	77	93, 91	NIL	*Light brown, coarse, shelly calcarenite
224	21/11 0600	15°57'S	120°58'E	146	91	NIL	*Light grey-brown, clayey, shelly calcarenite
225	21/11 0906	15°48'S	120°46'E	307	87	TR	Light grey-brown, very clayey, foraminiferal calcarenite
226	21/11 1250	16°01'S	120°35'E	347	77	TR	Grey-green, slightly shelly calcilutite
227	21/11 1900	16°16'S	120°45'E	330	98	10	Light grey-brown, shelly, foraminiferal calcarenite
228	21/11 2005	16°18'S	120°46'E	283	-	-	No sample
229	21/11 2330	16°29'S	120°59'E	143	293	4	*Grey-brown, clayey, shelly, foraminiferal calcarenite
230	22/11 0240	16°46'S	121°03'E	110	92	2	Grey-brown, shelly oolite
231	22/11 0600	17°03'S	121°07'E	106	96	TR	Light brown, shelly oolite
232	22/11 0900	17°20'S	121°11'E	95	92	3	*Brown, shelly oolite
233	22/11 1240	17°37'S	121°15'E	93	97	TR	Light brown, shelly, oolitic calcarenite
234	22/11 1615	17°55'S	121°19'E	79	89	TR	Green-brown, shelly, slightly oolitic calcarenite
235	22/11 1935	18°12'S	121°24'E	57	93	TR	Light-brown shelly, slightly oolitic calcarenite
236	26/11 1850	17°41'S	121°00'E	104	93	TR	Green-brown, slightly clayey, shelly oolite
237	26/11 2110	17°44'S	120°47'E	108	95	NIL	Light brown, shelly oolite
238	26/11 2345	17°49'S	120°28'E	119	-	-	No sample
239	27/11 0320	17°52'S	120°13'E	146	92	NIL	Grey-green, clayey, foraminiferal calcarenite
240	27/11 0550	17°56'S	119°57'E	148	85	NIL	Grey-green, clayey, foraminiferal calcarenite
241	27/11 0815	18°00'S	119°42'E	141	84	NIL	Grey-green, very clayey, foraminiferal calcarenite
242	27/11 1110	18°03'S	119°28'E	148	89	NIL	Grey-green, foraminiferal calcilutite
243	27/11 1450	18°06'S	119°15'E	121	90	NIL	Grey-green, foraminiferal calcilutite
244	27/11 1810	17°51'S	119°11'E	271	85	9	Green-brown, slightly clayey, foraminiferal calcarenite
245	27/11 2140	17°48'S	119°27'E	235	-	-	No sample
246	29/11 1345	17°27'S	120°53'E	117	97	1	Dark green-brown, shelly oolite
247	29/11 1705	17°13'S	120°50'E	128	95	5	*Grey-brown foraminiferal calcarenite
248	29/11 2020	16°58'S	120°47'E	194	97	3	Light brown, shelly, foraminiferal calcarenite
249	30/11 0110	16°49'S	120°42'E	322	89	NIL	Grey-brown, very clayey, shelly, foraminiferal calcarenite
250	30/11 0444	17°04'S	120°35'E	238	-	-	*No sample
251	30/11 0805	17°20'S	120°28'E	194	-	-	*No sample
252	30/11 1130	17°34'S	120°22'E	188	96	4	*Light brown, shelly, foraminiferal calcarenite
253	30/11 1550	17°54'S	120°28'E	121	90	10	*Light grey-brown, fine-grained shelly foraminiferal calcarenite
254	30/11 1850	18°06'S	120°31'E	91	80	NIL	Grey-green, fine-grained, shelly calcarenite
255	30/11 2210	18°11'S	120°15'E	102	-	-	Light grey-brown, slightly clayey, shelly oolite
256	1/12 0140	18°16'S	119°59'E	113	98	2	Light grey-brown slightly clayey, shelly oolite
257	1/12 0505	18°20'S	119°43'E	115	95	NIL	*Grey-green, very clayey, shelly oolite
258	1/12 0830	18°24'S	119°28'E	119	96	NIL	Light grey-green, very clayey, shelly oolite
259	1/12 1320	17°41'S	119°26'E	256	92	3	Light brown foraminiferal calcarenite
260	1/12 1550	17°32'S	119°30'E	320	93	NIL	Light brown shelly foraminiferal calcarenite
261	1/12 2008	17°42'S	119°47'E	247	80	9	Brown, foraminiferal calcarenite
262	1/12 2345	17°25'S	119°50'E	296	92	NIL	Grey-brown, clayey, foraminiferal calcarenite
263	2/12 0040	17°35'S	120°08'E	229	93	NIL	Light brown, shelly, foraminiferal calcarenite
264	2/12 0725	17°22'S	120°14'E	272	79	7	Dark green-brown, shelly, foraminiferal calcarenite
265	2/12 1045	17°05'S	120°21'E	344	80	NIL	Light brown shelly foraminiferal calcarenite
266	2/12 1830	16°52'S	120°46'E	256-347	-	-	No sample
267	3/12 0130	15°46'S	121°18'E	102	80	NIL	Light grey-brown clayey foraminiferal calcarenite
268	3/12 0445	15°40'S	121°03'E	293	89	TR	Light grey-brown clayey foraminiferal calcarenite
269	3/12 1140	14°54'S	121°36'E	296	-	-	*No sample
270	3/12 1500	14°52'S	122°04'E	119	94	TR	*Brown shelly oolite
271	3/12 1800	14°44'S	122°16'E	198	87	1	Light grey-green oolitic shelly calcilutite
272	3/12 2300	14°26'S	122°51'E	112	92	TR	Dark green-brown shelly oolite
273	4/12 0118	14°12'S	122°47'E	272	92	NIL	Green-brown foraminiferal calcarenite
274	4/12 0915	14°00'S	123°24'E	227	91	2	Grey-brown, shelly oolite
275	4/12 1300	13°32'S	123°40'E	190	87	2	Dark green-brown, shelly, foraminiferal calcarenite

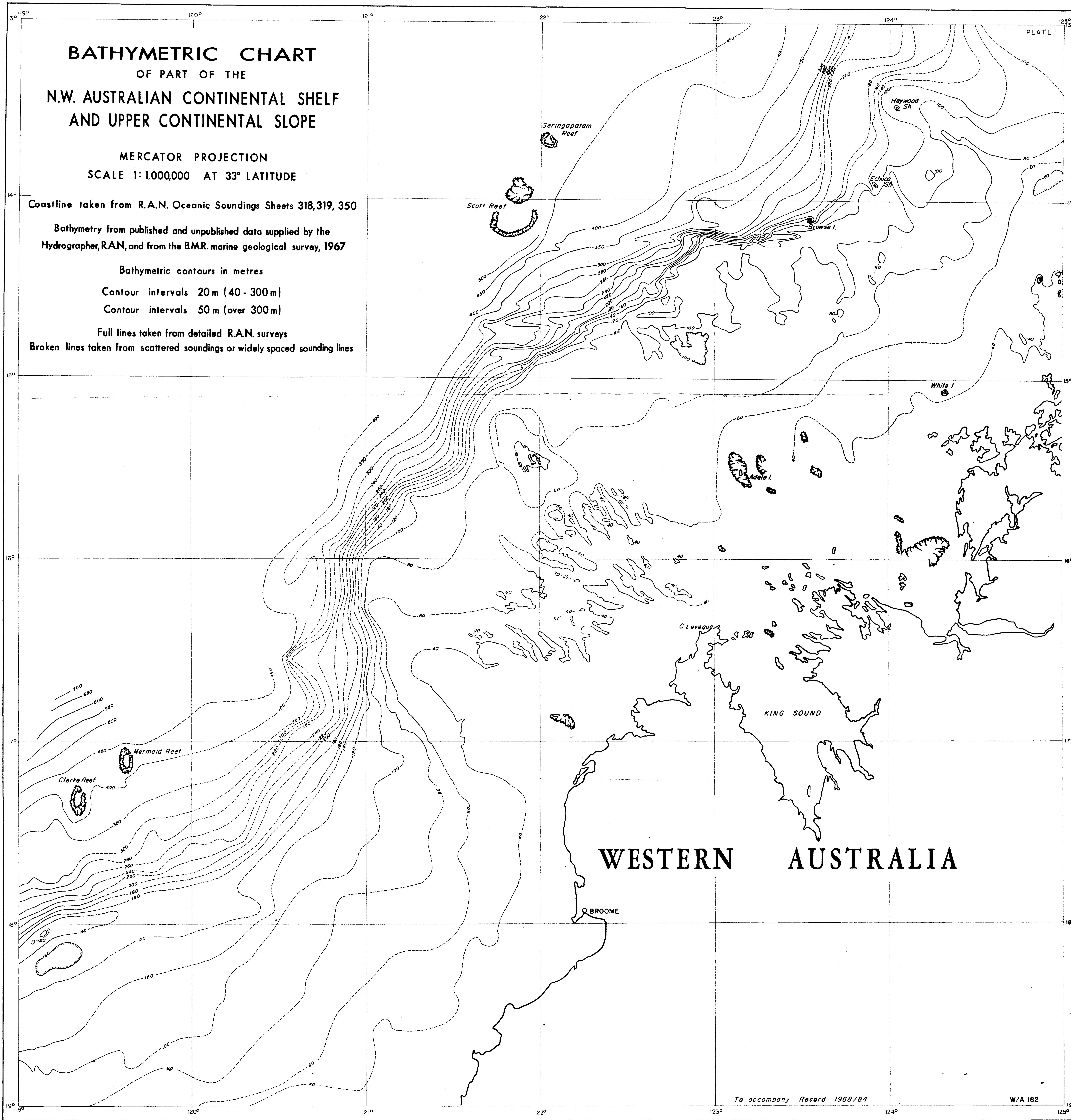


PLATE I
BATHYMETRIC CHART
OF PART OF THE
N.W. AUSTRALIAN CONTINENTAL SHELF
AND UPPER CONTINENTAL SLOPE
MERCATOR PROJECTION
SCALE 1: 1,000,000 AT 33° LATITUDE
Coastline taken from R.A.N. Oceanic Soundings Sheets 318, 319, 350
Bathymetry from published and unpublished data supplied by the Hydrographer, R.A.N., and from the B.M.R. marine geological survey, 1967
Bathymetric contours in metres
Contour intervals 20 m (40 - 300 m)
Contour intervals 50 m (over 300 m)
Full lines taken from detailed R.A.N. surveys
Broken lines taken from scattered soundings or widely spaced sounding lines
Seringapatam Reef
Scott Reef
Heywood Sh
Echuca Sh
Browse I.
White I
Adele I.
C. Leveque
KING SOUND
Mermaid Reef
Clerke Reef
WESTERN AUSTRALIA
BROOME
To accompany Record 1968/84
W/A 182

CROSS SECTIONS - N.W. AUSTRALIAN CONTINENTAL SHELF

LOCATION OF SECTIONS SHOWN ON FIGURE 5.

VERTICAL SCALE IN METRES. HORIZONTAL SCALE IN NAUTICAL MILES.