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MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

The Great Barrier Reef and the Great Barrier Reef Expedition 1973

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The Great Barrier Reef and the Great Barrier Reef Expedition 1973

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The Great Barrier Reef, the world's longest barrier reef, extends for 2000 km along the northeast coast of Australia. It is a complex feature, with outer ribbon reefs and inner platform and patch reefs of widely differing forms. Most previous work has concentrated in the extreme south (at Heron and One Tree Islands) or in the central sector (at Low Isles). The 1973 Expedition worked in the northern sector, from Cairns to the latitude of Cape Grafton (11° 30′ S). The main aim of the Expedition was to elucidate the recent history of the reefs, especially in response to Holocene sea level change. Evidence was sought from shallow coring, geophysical surveys, studies of reef and inter-reef sediments, observations on modern reef communities, and the analysis of the geology and geomorphology of reef islands. The work of the field parties in each of these areas is briefly reviewed and related to the questions to be discussed in the following papers.

Introduction

The Great Barrier Reef off the northeastern coast of Australia (figure 1) is the longest in the world. It extends for 2000 km from the latitude of New Guinea to nearly 24° S, and the shelf it encloses, which carries many small reefs, covers some 250000 km^2. Yet since Cook's first exploration in 1770 it has received less scientific attention than might have been expected, with the conspicuous exception of the work of the Great Barrier Reef Expedition 1928–29. More recently, Maxwell (1968) and his associates have done much to extend our knowledge of the Reef and especially its sediments, and work at research stations at Heron Island and One Tree Reef in the extreme south and at Lizard Island in the north is making a fundamental contribution to our understanding of coral reefs. In this introductory paper I sketch some aspects of the general nature and environment of the reefs, indicate the problems which the 1973 Royal Society and Universities of Queensland Expedition to the northern Great Barrier Reef sought to solve, and describe briefly the organization and conduct of the expedition.

General geomorphology

Many workers have stressed the variability in form of reef structures along the length of the Barrier. Both Yonge (1930) and Steers (1929) draw attention to the presence of long linear ribbon reefs forming an almost continuous barrier along the shelf edge north of Trinity Opening, off Cairns, in latitude 17° S, in contrast with the more scattered and less regular edge reefs south of that point. More recently Maxwell (1968) has defined three main reef provinces:

(1) The Northern Province, between 9° and 16° S, where the shelf is generally less than 40 m deep and where ribbon reefs extend along 71 % of the shelf edge. The width of the shelf varies from 25 to 60 km, but it narrows to a minimum of 13 km at Cape Melville.

(2) The Central Province, between 16° and 20° S, characterized by extensive platform reefs

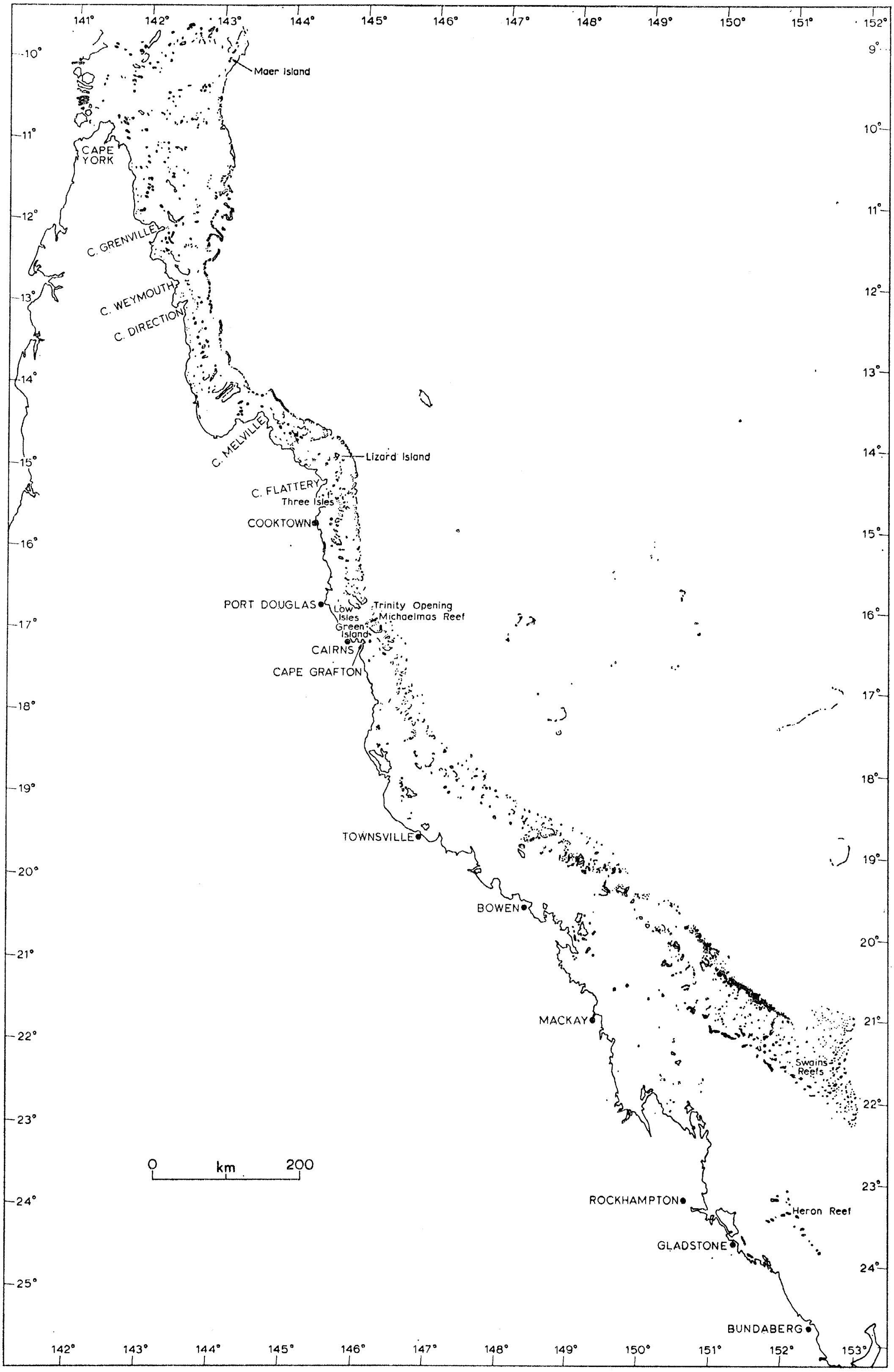

FIGURE 1. The Great Barrier Reef.

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on the shelf itself; shelf edge reefs are less continuous and extend along 45% of the edge; and the shelf itself is both wider and deeper (40–70 m) than in the north.

(3) The Southern Province, where the shelf reaches an extreme width of over 300 km and is more than 80 m deep; complex dissected reefs extend along only 36% of the shelf edge in the Swain Reefs, and within the barrier there are scattered platform reefs, some with well developed lagoons (in the Bunker and Capricorn Groups).

We are here concerned only with the reefs of the Northern Province, north of 16° S. Here the mainland coast consists of bold headlands of granite (Capes Weymouth, Direction, Melville and Grafton), with Palaeozoic and Mesozoic graywackes and conglomerates also forming promontories (Capes Bathurst, Tribulation, Flattery and Bedford, and Lookout Point) (Keyser & Lucas 1968). Between Cairns and Cape Melville much of the coast is bold (Bird 1970), but north of Cape Melville there are extensive progradational sequences of beach ridges and mangroves, with high Pleistocene siliceous dunes. 'High islands' of non-reef rocks are common across the coastal shelf. Lizard Island, the highest (359 m) is formed of Permian granite and stands only 18 km from the shelf edge; other granite islands include Howick, Forbes, Haggerstone, Sir Charles Hardy's, and the Cockburn Islands. Less rugged islands in the great indentation of Princess Charlotte's Bay (Flinder's, Clack, King Islands) consist of flat-lying Mesozoic sandstones. Further north, towards New Guinea, shelf edge islands such as Maer and Darnley are volcanic. The granite islands suggest a highly irregular basement on which the reef sequences have formed, while the presence of gently dipping sandstones hints that some at least of the extensive platform reefs might be built on such foundations.

The coral reefs of the Queensland shelf have been classified by Steers (1929), Spender (1930) and Fairbridge (1950) on the basis of size, form, location, and the nature of sedimentary accumulations on them. Maxwell (1968), using air photographs, has shown for the first time the true complexity and variability of the reefs, and proposes a new descriptive–genetic terminology and classification, much of which, in the present state of knowledge, must be inferential. For present purposes in the Northern Province we need only distinguish:

(1) Fringing reefs. These are not extensively developed in the Northern Region.

(2) Platform reefs. These are extensive reefs, located on the shelf itself, with rather featureless surfaces, generally with maximum dimensions of 5–10 km though some reach more than 20 km in length. Some carry leeward sand cays (such as Combe and Stapleton), but most have no permanent dry land.

(3) Ribbon reefs. These are linear reefs 5–25 km long and 300–500 m wide, extending along the shelf edge in the Northern Province, and interrupted by gaps or entrances with depths similar to those of the adjacent shelf. These reefs are little known, though Yonge Reef was briefly described by Stephenson, Stephenson, Tandy & Spender (1931, pp. 82–86).

(4) Small inner-shelf reefs. These include the 'low wooded islands' of Steers (1929, 1937) or 'island reefs' of Spender (1930): small reefs, usually only 1–2 km in greatest dimension, with complex assemblages of shingle ridges, exposed limestone platforms, mangrove swamps and sand cays, which, because of their diversity, offer the greatest possibilities of interpreting the recent record of reef growth and sedimentation. The headquarters of the 1928–29 Expedition was located on one of these (Low Isles); Steers (1937, 1938) studied many more in 1936; and, with their surrounding areas, they formed the main focus of the 1973 Expedition.

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Environment

Four main environmental factors are significant, both in interpreting the reefs themselves and in planning investigations of them. These factors are tides, winds, rainfall and cyclones.

Tides in the Great Barrier Reef area (Easton 1970) are variable but generally large in comparison with most other reef provinces. In the south the range at springs varies from 5 to 10 m, while in the Central Province it averages 3 m. In the north, it varies from 1.7 m at Cairns to 2.5 m at Cape York, but little is known of tides between these two locations (table 1). The tides are mixed semidiurnal, with the diurnal component increasing northwards. One fact of great ecological interest is that there is a seasonal reversal in the diurnal incidence of low water: in summer (December–January) tides low enough to give reef-top emersion occur at night, while in the winter (May–August) they occur during the day. All elevations in this study are referred to low water datum at Cairns, i.e. the mean height of the lower low waters at springs.

Table 1. Mean tidal range at springs in the Northern Province of the Great Barrier Reef

Data from Queensland Department of Harbours and Marine (1973).

locality	latitude S	range/m
Cairncross I.	11° 14½′	2.50
Hannibal I.	11° 35½′	2.44
Sir Charles Hardy's I.	11° 55′	1.83
Cape Grenville	11° 58′	2.01
Piper I.	12° 14½′	2.01
Restoration Rock	12° 37½′	1.77
Night I.	13° 10½′	1.77
Morris I.	13° 30′	1.80
Burkitt I.	13° 56½′	2.07
Pipon I.	14° 07½′	1.59
Flinders Is	14° 10′	1.89
Howick I.	14° 30′	1.77
Lizard I.	14° 40′	1.53
Low Wooded I.	15° 05′	1.77
Cooktown	15° 28′	1.77
Hope Is	15° 44′	1.71
Bailay Creek	16° 12′	1.28
Low I.	16° 23′	1.71
Port Douglas	16° 29′	1.77
Green I.	16° 45½′	1.71
Cairns	16° 55′	1.89
Fitzroy I.	16° 56′	1.77

Tidal levels in metres at Cairns are as follows (Queensland Department of Harbours and Marine 1973):

highest astronomical tide	2.9	mean low water neaps	1.2
mean high water springs	2.3	mean low water springs	0.5
mean high water neaps	1.6	lowest astronomical tide	−0.1

The Southeast Trades blow with great constancy and force in the Great Barrier Reef area for nine months of the year (March–November). Mean velocities are given as 18–29 km/h (10–15 knots), but north of Cairns these are frequently exceeded. As Steers (1929) noted, the Trades blow almost parallel to the trend of the coast, producing short, steep, difficult seas inside the Barrier; their effect on the morphology and ecology of the reefs has long been recognized (Hedley & Taylor 1908; Stephenson *et al.* 1931, p. 26). Cook sailed along the Barrier lagoon north of Cairns in August 1770, the time of year when the 1973 Expedition was in the field, and his journals are full of references to rough conditions: 'strong gales all this day' on the 8th, 'a prodigious great sea with breakers all around us' on the 9th, 'strong gales',

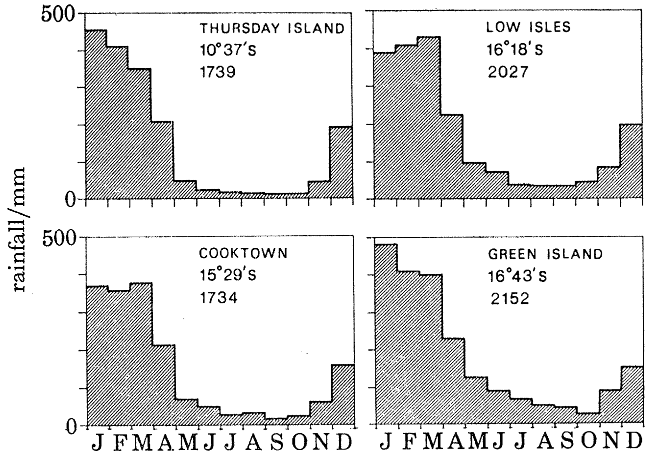

Figure 2. Monthly distribution of rainfall at stations on the northern Great Barrier Reef; the totals for each station are annual means in millimetres. Data from Brandon (1973).

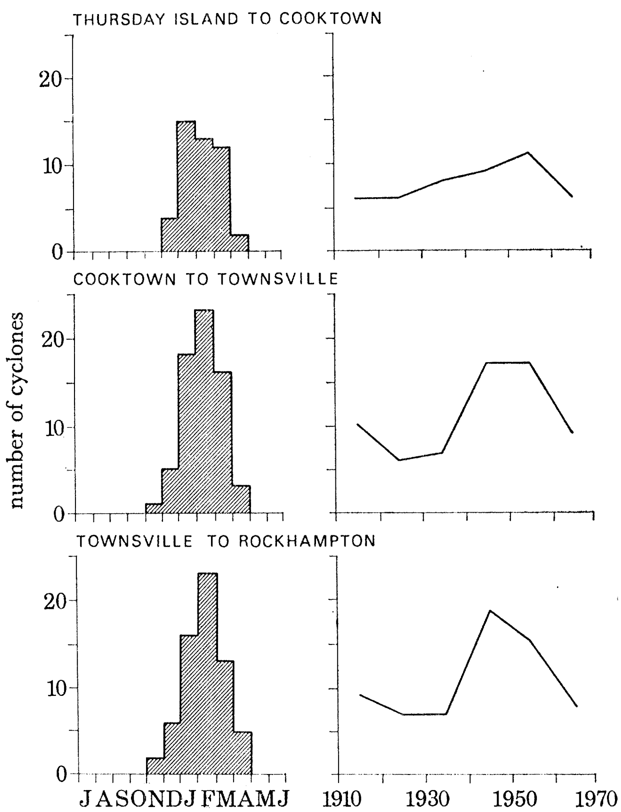

Figure 3. Mean monthly distribution of cyclones (left) and variation in frequency per decade (right) over the period of record (1910–69). Data from Coleman (1971).

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'hardly any intermission', 'fresh gales', 'such boisterous weather' (Beaglehole (ed.) 1955). When the Trades cease, for the three months December–February, the winds are northwesterly and less regular, with days of calm.

Rainfall varies considerably with latitude on the mainland coast of Queensland, even over short distances (Brandon 1973), but there are few records from islands on the coastal shelf. The Trades are dry, and rainfall is concentrated in the summer months December–April (figure 2). Annual totals average about 2000 mm in the southern part of the Northern Province (Green Island 2152 mm, Low Isles 2027 mm), and less than this further north (Cooktown 1734 mm, Thursday Island 1739 mm). It is possible that reef islands far from the mainland, such as Raine Island, are considerably drier; Willis Island in the Coral Sea has a 48 year mean of 1047 mm.

Finally, cyclones have important ecological and geomorphic effects, and also form a severe constraint on reef work. They are concentrated in the summer wet season. Records appear to show (figure 3) that they are less frequent in the northern part of the Northern Province than in the south, but this could reflect differences in recording rather than occurrence (Coleman 1971). The available data also indicate considerable variations in frequency over time, with highest frequencies about 1950 and lowest between 1920 and 1930.

Problems

Three sets of interrelated problems were investigated during the 1973 expedition.

Morphology

The gross form of the reefs clearly reflects both the history of growth and the effects of environmental constraints. Many workers have discussed the presumed effects of wave refraction on reef outline in plan, but generally without detailed consideration of the time scales involved or of the linkages between form and process. Maxwell (1968, pp. 139–142) has in addition shown how the orientation of reefs changes with latitude, possibly in response to environmental controls. Morphological adjustments take place in more complex ways than simply in plan-form, moreover, and we were particularly concerned with the detailed distribution of such sedimentary bodies as boulder tracts, shingle ramparts, sand and gravel flats, and sand cays on the reef tops.

Structure

Form is but the external expression of structures which themselves reflect growth histories constrained by both environmental influence and substrate topography. Earlier work on the development of individual reefs on the Queensland coast emphasized the importance of vertical growth followed by lateral extension and differentiation as the reef top approached sea level and thus began to modify its own environment (Fairbridge 1950). Studies elsewhere have suggested that many reef structures may thinly veneer topography developed on older reef limestones exposed during Pleistocene low sea levels (Stoddart 1969, 1973), and this interpretation has been documented for Caribbean reefs by Purdy (1974*a*, *b*) and in the Indian Ocean by Braithwaite, Taylor & Kennedy (1973), using both seismic techniques and drilling in the first case and stratigraphic analysis of exposed reefs in the second. Maxwell's studies (1968) of Queensland reef development emphasized simple growth processes rather than karst-inheritance, although on the basis of external morphology rather than internal structure, but in a later paper (Maxwell 1970) he did draw attention to the apparent inheritance of reef forms from those of older sedimentary structures. While there have been several deep bores on the Great Barrier Reef – at Michaelmas Cay (1926), Heron Island (1937), Anchor Cay (1969), Wreck Island (1960), and several recent deep holes in the south – the study of these has been concerned with the deeper rather than the shallower parts of the record, and there is considerable disagreement over dating and interpretation (Richards & Hill 1942; Lloyd 1973). The 1973 studies were therefore concerned not only with surficial structures, both of sediments and limestone bodies, but also with the upper few tens of metres of the reef record, to determine the sequence of phases of accretion and erosion in late Pleistocene and Holocene times. To interpret these records, some attention was also given to the distribution and composition of modern growth communities.

History

It is impossible to consider problems of reef development, structure and form without being concerned with the effects of Pleistocene changes of sea level on the reefs. There is broad agreement that the last major fall in sea level was to more than 100 m below the present level, and that between 10000 and 6000 a B.P. the sea rose at a mean rate of 1 m/100 a, but there is controversy over (1) the lowest level to which the sea last fell, (2) the occurrence, level and duration of still-stands during the subsequent transgression (and during earlier transgressions and regressions), and (3) the date at which sea level reached its present level, and its subsequent behaviour. With respect to this last period, arguments have been adduced for sea level stability over the last few thousand years; for continuing but decelerating transgression; and for oscillation both above and below the present level. Since corals are marine animals which can grow up only to specific tidal levels, they are clearly sensitive to such fluctuations, and it should therefore be possible to determine the interrelations of changing sea level and of reef form and structure. Hopefully the details of the reefs can be used to construct an unambiguous record of changing sea level.

Maxwell (1968, 1973) has erected a relative chronology of sea level change based on evidence of now-submerged terrestrial drainage patterns on the shelf, on the distribution of relict and contemporary shelf sediments, and on shelf and reef topography. This calls for still-stands at −102 m, −88 m, −66 m, an extensive stand at −29 m, a fall to another extensive stand at −59 m, a rise to a further important level at −37 m, a brief stand at −18 m, a transgression to +3 m, and a fall to present sea level. Except in so far as these stages can be related by elevation and sequence to the general eustatic curve of Fairbridge (1961), it is fair to note that Maxwell's interpretation is largely inferential, and is not yet supported either by radiometric evidence or by stratigraphic information on reef structures.

Figure 4 gives part of Milliman & Emery's (1968) curve of Holocene sea level, with, superimposed on it, the levels of Maxwell's inferred still-stands; it is not apparent how the formation of extensive terraces and ridges can have taken place during the time intervals of still-stands which might be accommodated within the general curve. It is, of course, possible that some of the features identified by Maxwell are older than the last major transgression. Figure 4 also shows two low-level ^{14}C dates on Australian material: one of 13860 ± 220 a B.P. at −175 m on the southern Great Barrier Reef (Veeh & Veevers 1970) and one of 16910 ± 500 a B.P. at −132 m in the Timor Sea (Van Andel & Veevers 1967, p. 100): these may define the trough of the curve in the Australian region.

The evidence of very recent oscillations is controversial (Thom, Hails & Martin 1969; Gill & Hopley 1972; Cook & Polach 1973; Thom & Chappell 1975), but nevertheless crucial to an interpretation of recent reef history. Much of the work of the expedition was concerned with resolving ambiguities in the evidence for positive and negative sea level changes in the northern Great Barrier Reef area, ambiguities increased because of the macrotidal conditions and also because of the complex relation between growing marine organisms and tidal levels.

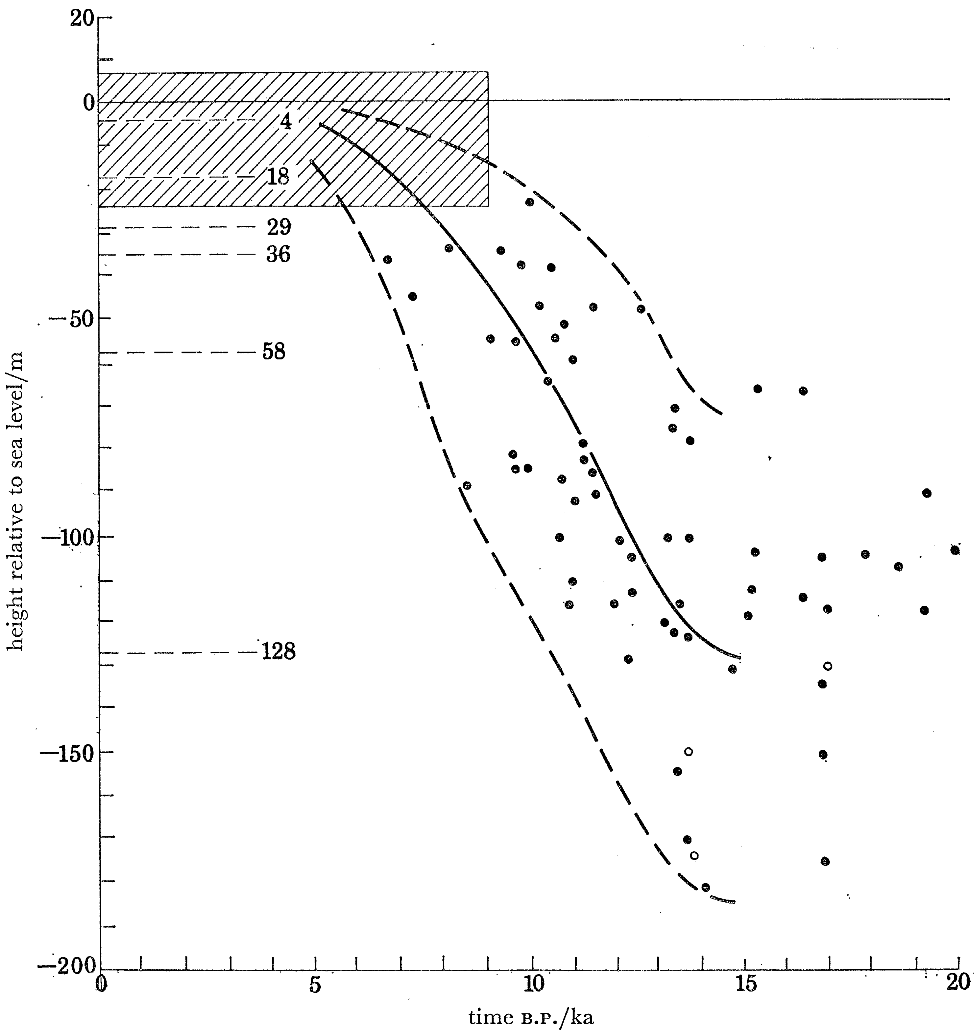

Figure 4. Holocene rise in sea level, after Milliman & Emery (1968). The open circles are additional data point for Australian samples published by Van Andel & Veevers (1967) and Veeh & Veevers (1970). The levels on the left of the graph are those of sea level still-stands inferred by Maxwell (1968, 1973). The shaded area represents the controversial recent period of sea level history with which the Expedition was concerned.

Organization of the Expedition

The Expedition, which began in mid-July and lasted until mid-November 1973, was divided into three phases, each concentrating on different themes in different areas. Table 2 lists the members of the Expedition with their main research interests. The Expedition used several vessels for varying periods: *Odyssey* was the main vessel for transporting personnel and

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also for the geophysical programme; *Calypso II* was used for the sediment sampling programme; *Privateer*, a barge, was used for transporting the drilling rig during Phase I; and *James Kirby*, the James Cook University research vessel, was used north of Cape Melville during Phase III. The Expedition also worked closely with the Royal Australian Navy during Phase II.

Table 2. Members of the Expedition

J. Beaton, archaeologist, Department of Prehistory, Australian National University, Canberra (Phase II, part).
A. L. Bloom, geomorphologist, Department of Geology, Cornell University, New York (Phase II, part).
J. Collins, marine biologist, School of Biological Sciences, James Cook University, Townsville (Phase III).
P. Flood, sedimentologist, Department of Geology, University of Queensland, Brisbane (Phase I).
P. E. Gibbs, marine biologist, Marine Biological Association of the United Kingdom, Plymouth (Phases I–III).
D. Hopley, geomorphologist, Department of Geography, James Cook University of North Queensland, Townsville (Phases II, part, and III).
R. C. L. Hudson, marine biologist, School of Biological Sciences, James Cook University, Townsville (Phase III).
N. Kelland, geophysicist, Coastal Sedimentation Unit, Institute of Oceanographic Sciences, Taunton (Phase II, part).
E. Laundon, geophysics technician, Department of Geology, University of Queensland, Brisbane (Phase II, part).
R. F. McLean, geomorphologist, Department of Biogeography and Geomorphology, Australian National University, Canberra (Phases I and II).
M. Morton, sedimentology technician, Department of Geology, University of Queensland, Brisbane (Phase II, part).
G. R. Orme, deputy leader, sedimentologist, Department of Geology, University of Queensland, Brisbane (Phases I, part, and II).
H. A. Polach, radiometric dating, Radiocarbon Dating Laboratory, Australian National University, Canberra (Phase I, part).
I. R. Price, marine biologist, School of Biological Sciences, James Cook University, Townsville (Phase III, part).
G. E. G. Sargent, geophysicist, Department of Geology, University of Queensland, Brisbane (Phase II, part).
T. P. Scoffin, sedimentologist, Grant Institute of Geology, University of Edinburgh, Edinburgh (Phases I and II).
K. Shaw, drilling technician, Department of Biogeography and Geomorphology, Australian National University, Canberra (Phase I).
A. Smith, sedimentology technician, Department of Geology, University of Queensland, Brisbane (Phases I and II, part).
D. R. Stoddart, Expedition Leader, geomorphologist, Department of Geography, University of Cambridge, Cambridge (Phases I–III).
B. G. Thom, drilling operation, Department of Biogeography and Geomorphology, Australian National University, Canberra (Phase I).
J. E. N. Veron, marine biologist, School of Biological Sciences, James Cook University, Townsville (Phase I, part, and leader, Phase III).
J. Webb, geophysicist, Department of Geology, University of Queensland, Brisbane (Phase II, part).
L. P. Zann, marine biologist, School of Biological Sciences, James Cook University, Townsville (Phase III, part).
L. Zell, marine biology technician, School of Biological Sciences, James Cook University, Townsville (Phases I, II–part, III).

Phase I (figures 8 and 9)

Phase I was an initial phase of one month (19 July–19 August) in the Howick Group, centred at Howick and Bewick Islands. A team from the Australian National University under B. G. Thom carried out shallow drilling on Bewick and Stapleton Islands. A sedimentological team comprising G. R. Orme, T. P. Scoffin and P. G. Flood, working from *Calypso II*, sampled shelf and reef-top sediments. A geomorphological team of D. R. Stoddart and R. F. McLean studied island geomorphology and sediments, mainly from *Odyssey*. In addition, J. E. N. Veron collected corals, H. Polach supervised the collection of samples for radiometric dating, and P. E. Gibbs collected benthic fauna. This phase ended in mid-August when the Expedition returned to Cairns; it was followed by a charter flight over the areas already visited, for photographic purposes.

Phase II (figures 5–9)

Phase II extended from 20 August to 14 October and was logistically complex, partly because of the need to provide ship time for the geophysical party, partly to coordinate the programme with the movements of the Royal Australian Navy Hi-fix survey teams. The geomorphological and sedimentological parties therefore separated from the *Odyssey* and occupied a series of

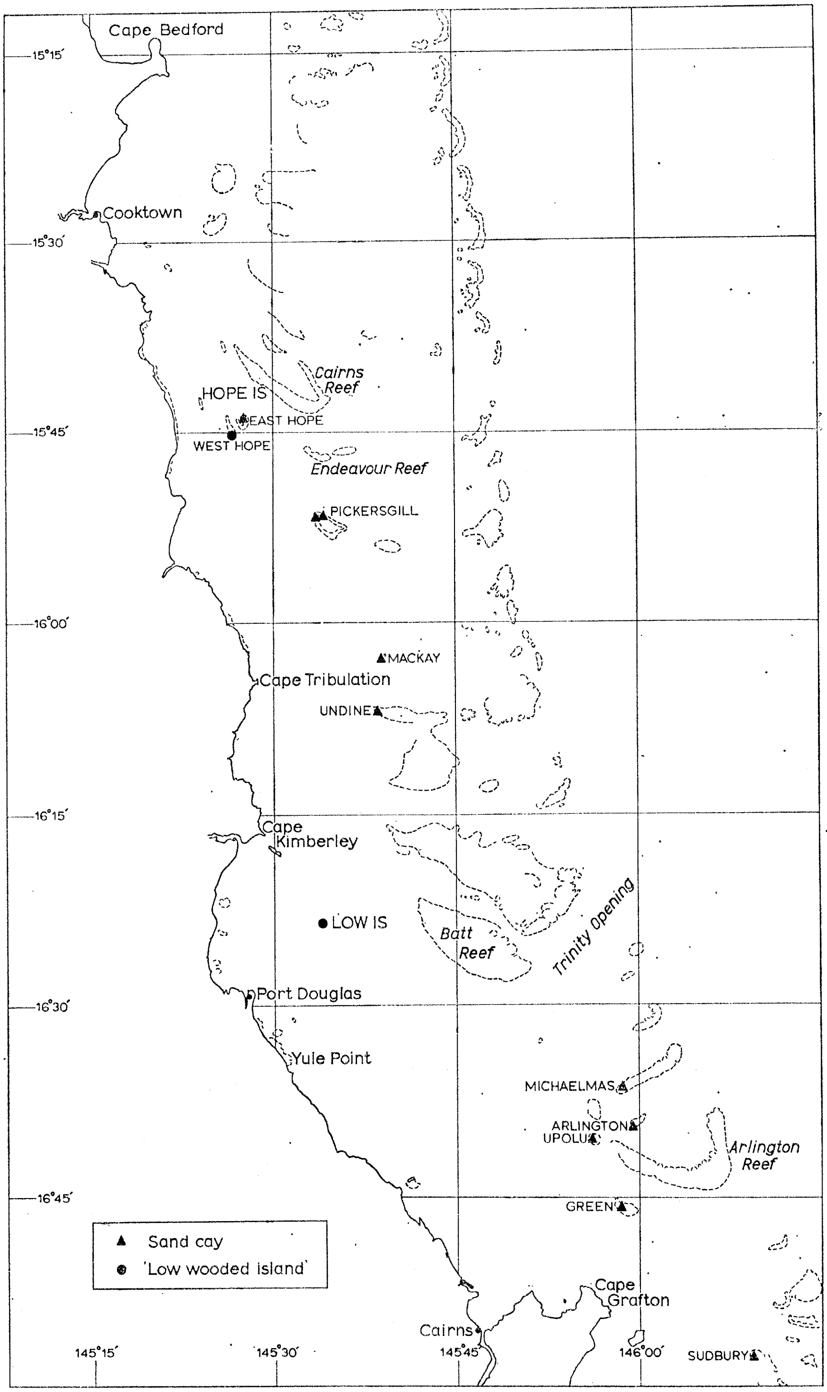

FIGURE 5. Southern sector of the Northern Province: reef islands mapped.

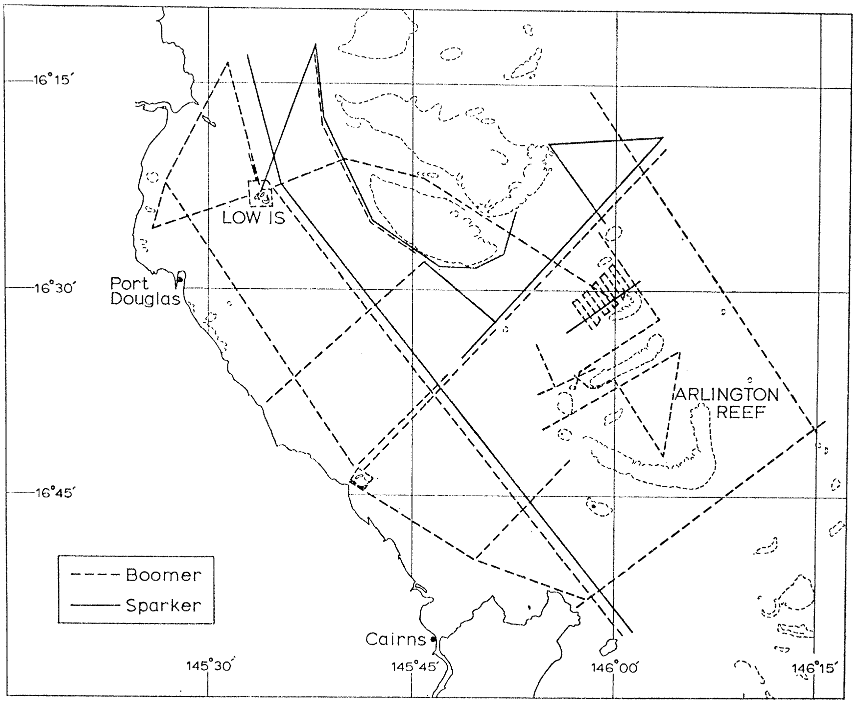

FIGURE 6. Southern sector of the Northern Province: seismic profiles.

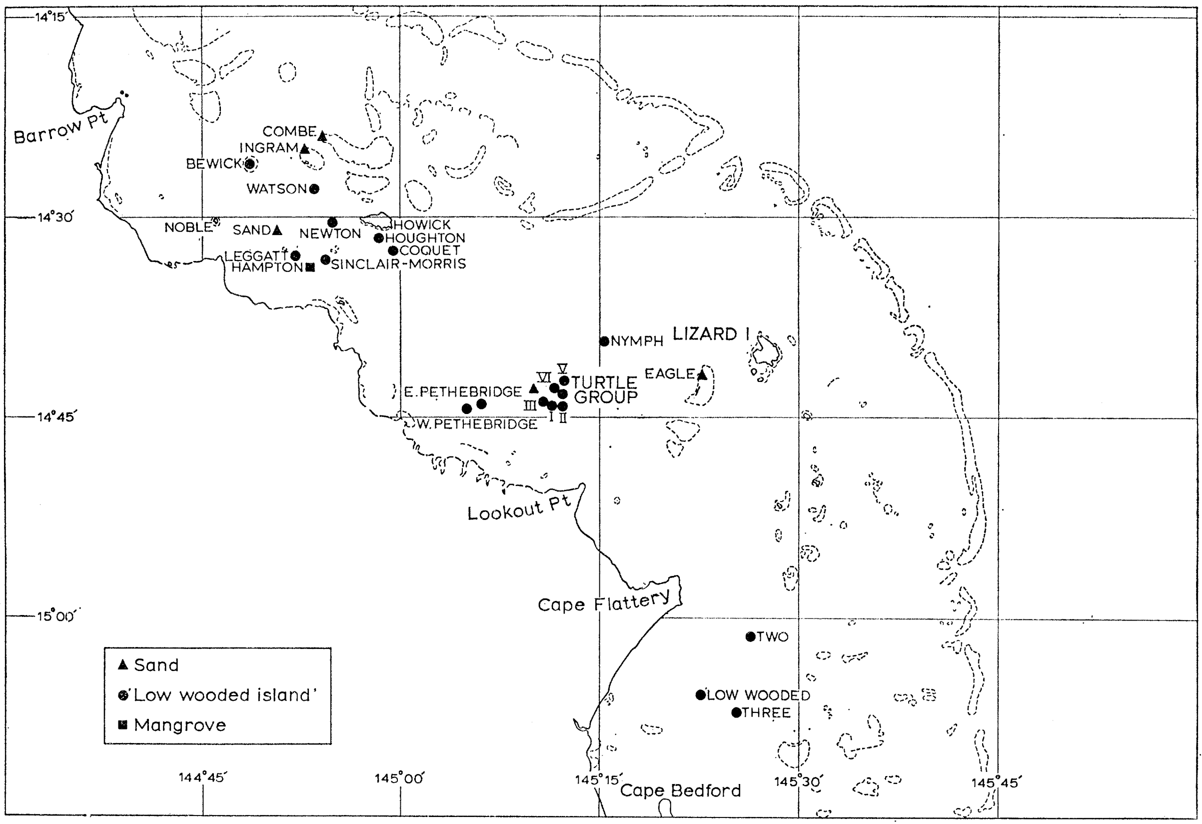

FIGURE 7. Central sector of the Northern Province: reef islands mapped.

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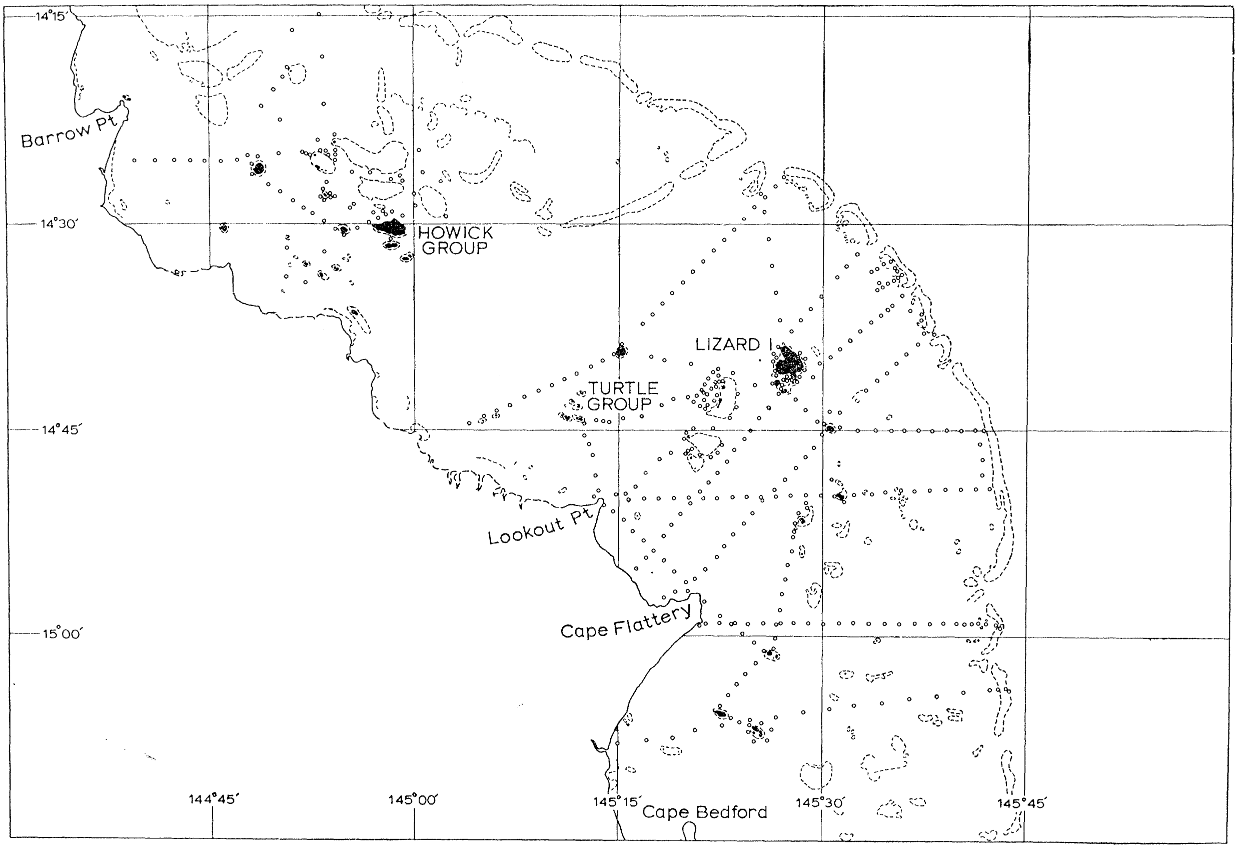

FIGURE 8. Central sector of the Northern Province: shelf sediment samples.

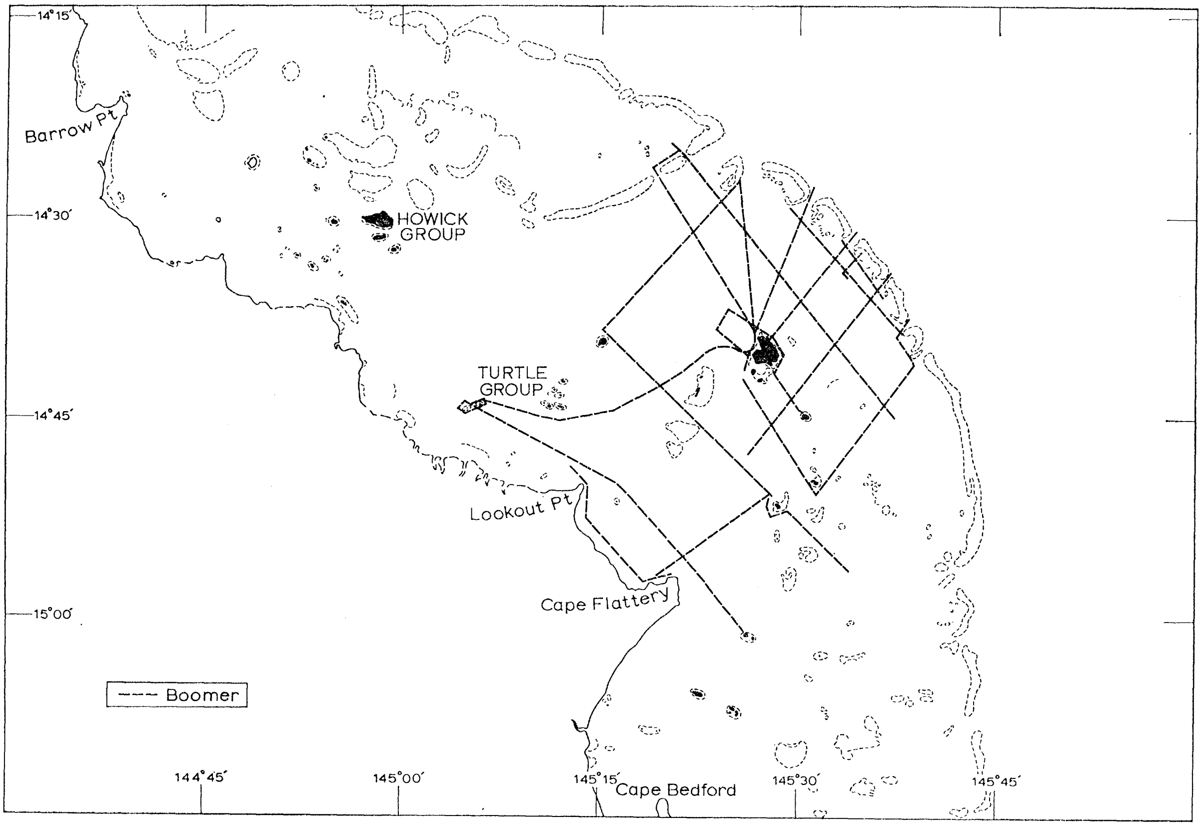

FIGURE 9. Central sector of the Northern Province: seismic profiles.

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shore camps, serviced by *Calypso II*. The geophysical work was carried out with *Odyssey*, fitted with Hi-fix equipment operated by R.A.N. personnel.

The shore party comprised D. R. Stoddart, P. E. Gibbs, T. P. Scoffin and R. F. McLean. It occupied camps at Low Isles (headquarters of the 1928–29 Expedition) from 23–29 August, East Hope Island from 29 August to 5 September, and Three Isles from 6 to 26 September. D. Hopley joined the Expedition during this last period. Each of these camps was made the

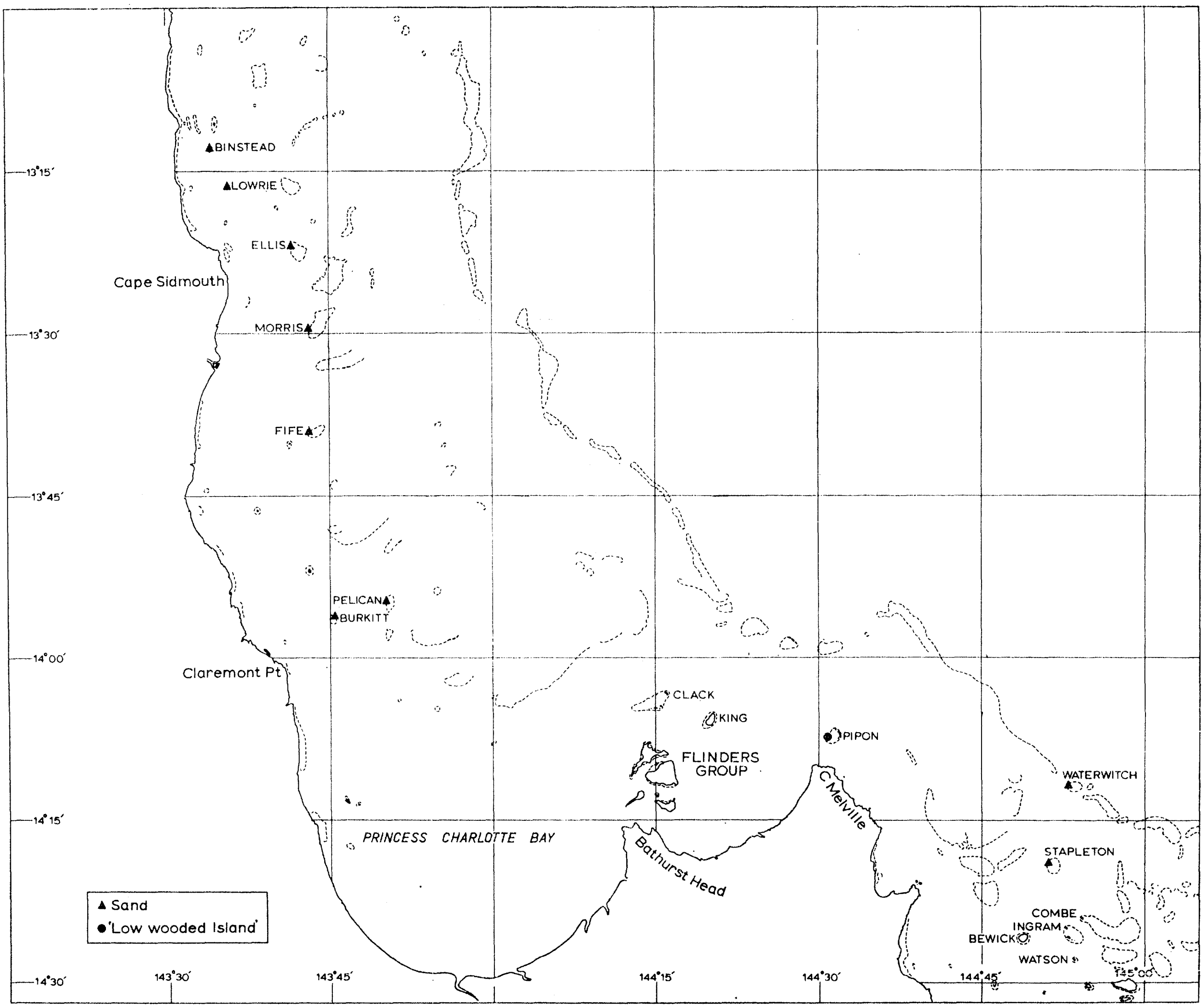

Figure 10. Northern sector of the Northern Province: reef islands mapped.

basis for studies of reefs and islands in the vicinity. Meanwhile the geophysical party with *Odyssey* worked its first area between Cairns, Arlington Reef and Low Isles (figure 6). The Royal Australian Navy then moved the Hi-fix navigation system to the area between Lizard Island and Cape Flattery. While *Odyssey* carried out geophysical surveys here (figure 9), the shore party, now joined by A. L. Bloom, moved north to the Turtle Islands, where it worked with *Calypso II* from 27 September to 14 October. At the end of this period the Expedition regrouped in Cairns after seven weeks in the field.

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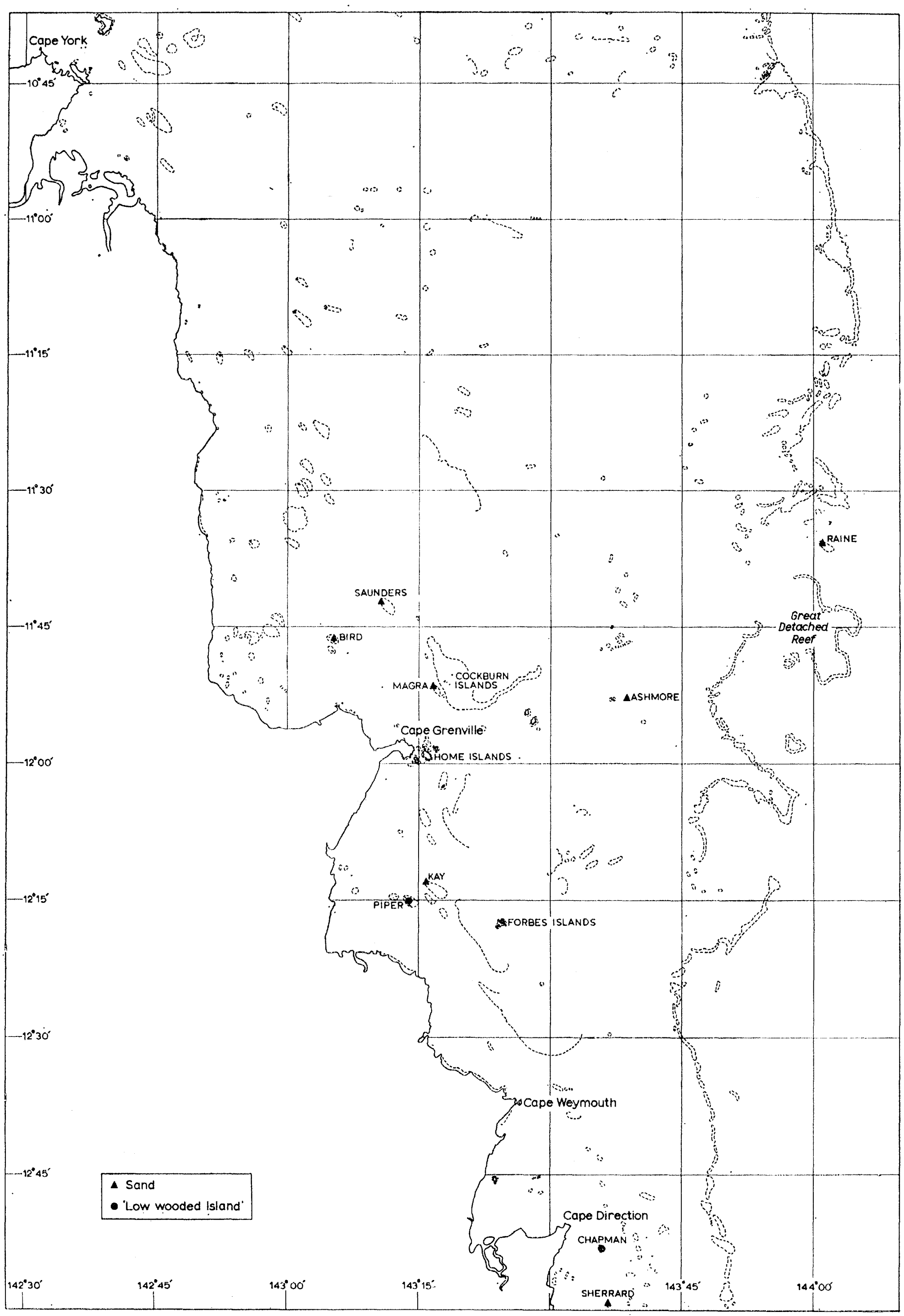

FIGURE 11. Far northern sector of the Northern Province: reef islands mapped.

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Phase III (figures 10 and 11)

The Expedition again moved north on 20 October to Lizard, the Howick Group and Pipon Island, to rendezvous with James Cook University's research vessel *James Kirby* with a party from Townsville under J. E. N. Veron. *Odyssey* then returned to Cairns at the end of its charter. *Calypso II* also returned to Cooktown, but its charter was extended so that Orme and Flood could complete the sediment sampling programme of Phases I and II (figure 8). *James Kirby* with Stoddart, Gibbs, Hopley and Veron's biological party then moved north from Cape Melville to Cape Grenville, finally reaching Raine Island and the Great Detached Reef in early November. This was the furthest north point that the Expedition worked (11° 36′ N). Stoddart, Gibbs and Hopley were then landed at Iron Range and flew to Cairns, and *James Kirby* worked south back to Townsville. The Expedition effectively ended its field work in mid-November.

Summary of scientific projects

Geomorphology

Geomorphological studies were concentrated on reef islands, including simple sand cays, shingle islands, mangrove islands, and 'low wooded islands'. Approximately 60 islands were mapped at scales varying from 1 : 500 to 1 : 2500 by Stoddart. Profiles were levelled on many of these and related to the Cairns datum by Stoddart and McLean during Phases I and II, and by Hopley and Bloom during the latter part of Phase II. The geomorphological work was in the hands of Stoddart and Hopley during Phase III. The aim of this work was to identify and describe the sediment bodies which have formed islands during Holocene time, and to map the major vegetation units on them. These studies also provided basic data for some of the following projects, and provided data for comparison with maps made in previous years, notably by Steers (1938) in 1936.

Island sediments and rocks

McLean and Scoffin concentrated on the surficial sediments of the islands (sand and shingle of ridges, ramparts and cays) and cemented materials (upper and lower platforms and beach-rocks). They were concerned with the composition and origin of the sediments; McLean also worked on dating and on post-depositional changes in clast morphology, and Scoffin on the diagenetic fabrics and histories of the cemented rocks. Hopley studied beach-rock morphology, and Bloom the mangrove sediments.

Drilling programme

The Australian National University Gemco drill was used for coring on Bewick and Stapleton Islands during Phase I. This work was supervised by Thom with the assistance of Orme: the drilling itself was in the hands of Karl Shaw. The rig weighed 1900 kg and was not easy to handle on steep beaches with a high tidal range. Because of tide and weather conditions it was not possible to relocate the rig at Noble Island, the third site selected, and bad weather in fact prevented the barge *Privateer* returning to Cooktown with the rig until long after the charter period had ended. Drilling was carried out to 19.5 m on Stapleton and 29 m on Bewick.

Shelf sediment sampling

During Phase I the bottom sediment sampling programme from *Calypso II* was in the hands of Flood, Scoffin and Smith. Samples were collected both from inter-reef shelf areas and also from reef flats in the Howick Group. Gibbs also took dredge samples to extract bottom fauna. During Phase II Scoffin sampled in the area of Arlington Reef, Low Isles and the Hope Islands, again collecting shelf and reef flat material. Scoffin also took more samples during Phase III in the Turtle Islands. During the supplementary charter of *Calypso II* Orme sampled intensively in the area between Lizard Island and the mainland, and this area has the most intensive bottom-sampling coverage of the expedition. Most samples were split, one half being treated with peroxide and the other preserved in alcohol.

Geophysics

The geophysical programme was operated from *Odyssey* during Phase II, with two high resolution boomers, two streamers, an E. G. & G. recorder, and side-scan sonar. Positions were accurately fixed by using a Decca Hi-fix receiver supplied and installed in *Odyssey* by the Hydrographic Department, Royal Australian Navy, which also set up shore stations and seconded Petty Officer Clyde Hillsdon to the Expedition while the equipment was in use. The aim of this programme was to determine sub-bottom sedimentary structures and the contact between reef and non-reef rocks. In spite of difficult weather, several hundred kilometres of records were obtained, most comprehensively in the northern area between Lizard Island and the mainland; this is also the area of most intensive sediment sampling. The geophysical programme was operated by Webb, Kelland and Laundon during the first part of Phase II, and by Orme and Sargent during the second.

Dating programme

Particular attention was paid throughout the Expedition to the collection of critical material from cores, surface sediment samples, and surface rocks for radiocarbon dating, to determine more precisely the sequence of Holocene events and to give a time dimension to the geomorphological record. Polach of the Australian National University Radiocarbon Dating Laboratory joined the Expedition during Phase I to advise on sampling techniques, and also provided preliminary dates on samples while the Expedition was still in the field. Collection of samples was largely in the hands of McLean, Hopley and Bloom, with Thom responsible for the core samples.

Reef zonation and composition

Veron with Thom made initial collections and reef transects during Phase I in the Howick Group, but the main work on reef zonation took place from *James Kirby* during Phase III. Studies were made of ribbon reefs on the shelf edge at Great Detached Reef (11° 40′ S) and Tijou Reef (13° 08′ S): quantitative surveys using line transect methods were made on the reef front, reef flat and back-reef by Veron, Price and Hudson. Less intensive studies for comparative and faunistic purposes were made at other sites. Zell, Veron and Hudson made large collections of living corals during Phase III, to supplement other collections made during Phases I and II by Zell. Corals were collected from a total of 33 sites, the specimens from each site varying in number from 20 to 300.

Other benthic fauna

Gibbs studied the bottom fauna of the shelf from dredge collections, and also the infauna of unconsolidated sediments on reef flats. Collections were made of polychaetes, echinoderms, crustaceans, molluscs and other groups. Particular attention was paid to a resurvey of Low Isles and Three Isles to compare with faunistic surveys in 1928–29 and 1954. Price collected benthic algae during Phase III as part of the reef transect surveys.

Terrestrial flora

Stoddart collected vascular plants on 40 islands during the geomorphological surveys and mapping. The collections totalled over 1100 numbers, mostly in six sets. The first set has been retained by the Queensland Herbarium in Brisbane, where the material was sorted and dried as it arrived from the field, and the other sets are being distributed by the Department of Botany, National Museum of Natural History, Washington. Determination of the material has been carried out by staff of the Queensland Herbarium under its Director, Mr S. Everist, and by Dr F. R. Fosberg in Washington.

Prehistory

John Beaton from the Australian National University joined the Expedition for the first part of Phase III to carry out a reconnaissance survey for prehistoric habitation sites which could have geomorphological implications. Surveys were made on Lizard, Howick, Bewick, Noble and Pipon Islands, and were supplemented by other observations by McLean.

Clearly an expedition of such magnitude and complexity, spending such a high proportion of its total time in active fieldwork, would not have been possible without an immense amount of support from many individuals and organizations. The captains and crews of the vessels used made it possible to remain at work and carry out a crowded programme, often in very difficult conditions. The Department of Geology, University of Queensland, was the Expedition's main base in Australia, and not only lent much of the geophysical and other equipment but also seconded technical staff. Other geophysical equipment was loaned by the Natural Environment Research Council in England. The Royal Australian Navy generously cooperated with the Expedition during the geophysical surveys, and loaned Decca Hi-fix equipment and an operator for use in *Odyssey*. The Navy also allowed us the use of a store in Cairns for both equipment and an increasing quantity of specimens. Phase III of the Expedition was made possible by the provision of *James Kirby* by James Cook University of North Queensland. Drilling equipment during Phase I was loaned by the Department of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National University.

The Expedition was only made possible by the generous financial support given by the Royal Society of London, the University of Queensland in Brisbane, and James Cook University in Townsville, as well as by many other institutions. I acknowledge in particular the support of the Southern Zone Research Committee of the Royal Society, which was initially responsible for planning the Expedition, the Expedition Committee established by the University of Queensland, which overlooked its affairs in Australia, and the officers of the Great Barrier Reef Committee, notably Dr Owen Jones and Dr Patricia Mather, for many kindnesses. All members of the Expedition thank Professor J. A. Steers and Sir Maurice Yonge, who, as members of

the 1928–29 Expedition, supported this further study and whose work provided such a stimulus in the field.

Lastly, the smooth operation of the Expedition owed a very great deal to the tolerance and goodwill of all those involved in it, and their willingness to accept an often complex programme so that all the participants could complete their individual projects.

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