Lithofacies Analysis, Southern Part of the Great Barrier Reef

by
W. G. H. MAXWELL and W. R. MAIKLEM

Price: Three Shillings

University of Queensland Papers
Department of Geology
Volume V Number 11

THE UNIVERSITY OF QUEENSLAND PRESS
St. Lucia

9 December 1964

WHOLLY SET UP AND PRINTED IN AUSTRALIA BY
WATSON FERGUSON AND COMPANY, BRISBANE, QUEENSLAND
1964

REGISTERED IN AUSTRALIA FOR TRANSMISSION BY POST AS A BOOK

LITHOFACIES ANALYSIS, SOUTHERN PART OF THE GREAT BARRIER REEF

ABSTRACT. The southern region of the Great Barrier Reef occupies an area of 12,000 square miles, mainly on the Continental Shelf between latitudes 22°S and 24°S. Bottom sampling of the area has led to a lithofacies analysis in which carbonate, terrigenous, and intermediate facies have been recognized and subdivided further on granulometric data. The lithofacies pattern conforms with our present knowledge of the physiography, hydrography, and source influences of the area. Present evidence indicates that the sediments are entirely detrital or detrital-organic in origin. No material of inorganic-chemical derivation has been recognized.

REGIONAL SETTING

The region surveyed extends north-eastward from the Queensland coastline between latitudes 22°30′S and 24°S, and converges on the ocean side of the outer Barrier at meridian 152°50′E. Total area covered is approximately 12,000 square miles, which is approximately one-eighth of the Great Barrier Reef province. Map coverage is provided by two hydrographic charts (Admiralty Charts 345, 346) on the scale 1 : 300,000. Except for the Heron Island Reef there is no aerial photographic coverage. The Swain Reefs are still uncharted. Sample locations are shown as small dots on Figures 1–6 and are numbered on Figure 7. Regularly spaced larger dots on Figures 2–6 form part of the patterns indicating facies as shown on the legend.

Physiography

Physiographically the region falls into seven natural divisions (Fig. 1): the Near-Shore Zone, Inner Shallow Shelf, Western Marginal Shelf (including the Capricorn-Bunker Groups), Southern Shelf Embayment (Capricorn Channel), Eastern Marginal Shelf (Swain Reefs), Continental Slope, Western Coral Sea Continental Borderland.

1. *The Near-Shore Zone* includes the bays, estuaries, and sheltered waters behind the coastal islands and it extends seaward to approximately the 5-fathom mark. It is characterized by shallow yet widely varying topography—bars and shoals separated by deeper channels.

2. *The Inner Shallow Shelf* extends from the Near-Shore Zone to approximately the 20-fathom line. It has a very slight seaward gradient. Gentle east-west swells are responsible for the main relief. Width of the zone ranges from 2 to 30 miles.

3. *The Western Marginal Shelf* is delineated approximately by the 20- and 35-fathom lines. It includes the Capricorn and Bunker Groups of reefs and reefal banks, which rise from east-west swells and from the shelf edge. Reef growth is restricted to the latitudes 24°30′S to 22°30′S. The width varies from 5 to 40 miles.

4. *The Southern Shelf Embayment* occupies the depressed part of the shelf between the Western and Eastern Marginal Shelf Zones. It is defined approximately by the 35-fathom contour. There is a weak south-easterly gradient (0.03° or 2 feet per mile) which increases near the 60-fathom line to approximately 0.2° (18 feet per mile) and again at the 100-fathom line to 0.6° (50 feet per mile). East-west swells are conspicuous along the western side of the embayment. The average width of the embayment is 55 miles in the south, decreasing to about 10 miles in the north.

5. *The Eastern Marginal Shelf* forms an irregular broken platform, 35 to 40 miles wide, which rises steeply from the Southern Shelf Embayment (Capricorn Channel). Except for some of the main channels within the reef complex, depths rarely exceed 30 fathoms. The eastern edge of the Swain Reefs forms the main outer barrier, a line of nearly continuous reefs, beyond which the sea floor falls gradually eastward at about 0.25° (21 feet per mile). This gradient is much less than that of the Continental Slope off the Capricorn-Bunker Groups.

6. *The Continental Slope.* The upper limit of the Continental Slope appears to lie between the 40- and 50-fathom contour interval off the Capricorn-Bunker Groups where it is parallel with the coastline. It descends on a gradient of almost 2° (100 feet per mile) to a depth of about 160 fathoms where it merges with the Western Coral Sea Continental Borderland. Off the Southern Shelf Embayment the gradient below 60 fathoms is of the order of 0.2° to 0.6° which is comparable with that of the Coral Sea Continental Borderland. Therefore the Continental Slope is not recognizable as a separate topographic feature here. The sea floor east of the Swains behaves likewise.

7. *The Western Coral Sea Continental Borderland* extends eastward from the 160-fathom line off the Capricorn-Bunker Groups and grades northward towards the Southern Shelf Embayment with the only recognizable break at the 60-fathom line. The regional gradient to the south-east is of the order of 0.5° (45 feet per mile). The gradient increases abruptly to almost 3° (275 feet per mile) about 80 miles south-east of the Swain Reefs, where the Continental Slope reappears.

Land provenance

Lower Palaeozoic low grade metamorphic rocks (phyllite and greywacke), Upper Palaeozoic greywacke, limestone and intermediate to basic volcanics, and Cainozoic gravel, sand, and clay are the dominant lithologies of the land adjacent to this part of the reef. Granitic rock is restricted to small areas. The physiographic character of the entire region is generally mature. The climate is sub-tropical with moderate to low rainfall. As a consequence weathering processes are prolonged and predominantly chemical. Because of the lithological, physiographic, and climatic factors the sedimentary loads of streams are mainly argillaceous.

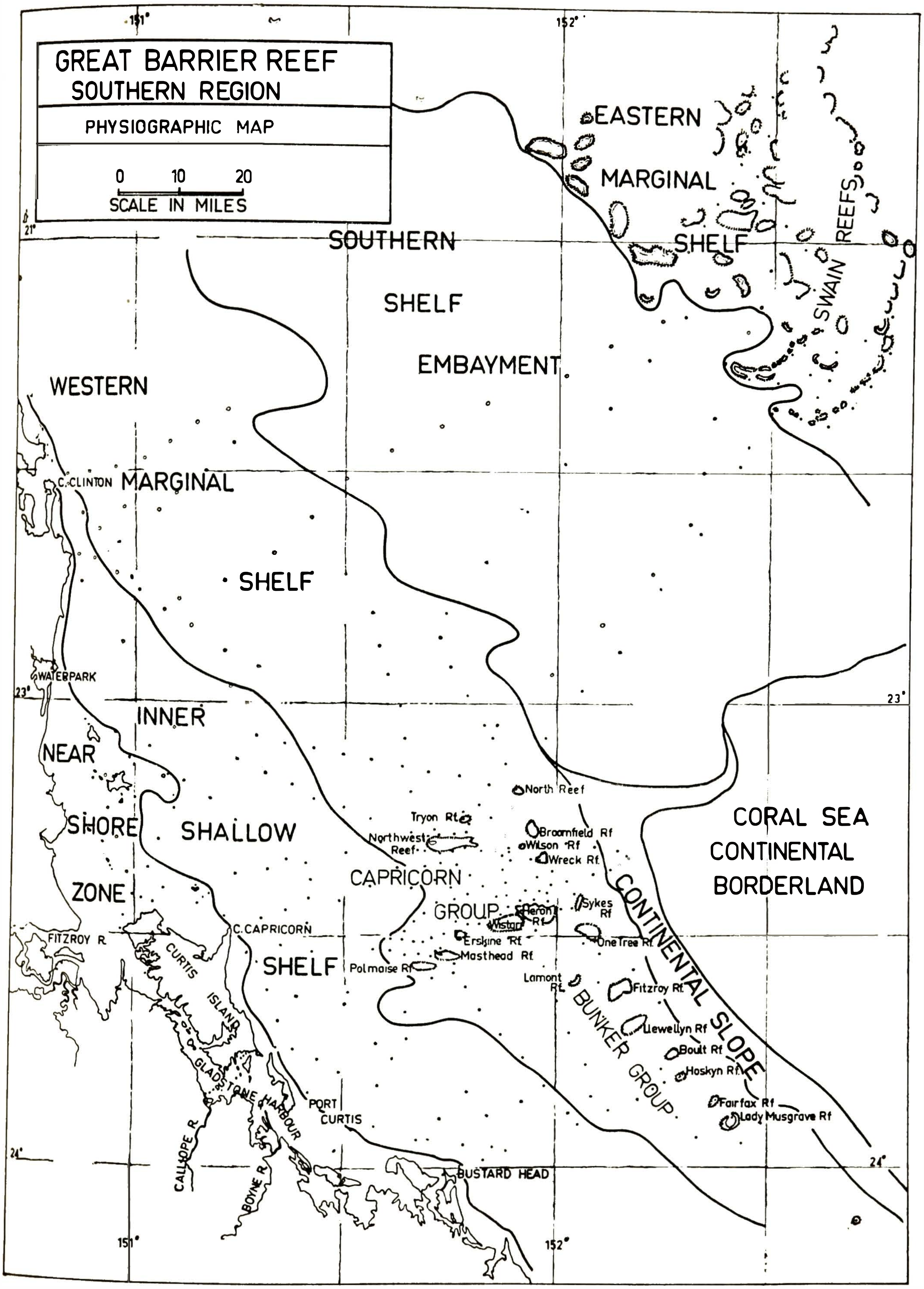

FIG. 1.—Physiographic map of the southern part of the Great Barrier Reef.

Drainage is controlled by the major Fitzroy River System and the smaller Boyne and Calliope rivers. The mean annual discharge of the Fitzroy River (measured by the Queensland Irrigation and Water Supply Commission from 1922 to 1955) is 4,050,000 acre feet or 1.2 cubic miles. A value of 0.1 cubic miles has been measured for the Boyne. No data is available on the Calliope, but it is the smallest stream and probably has a discharge of less than 0.1 cubic miles. (The estimated water volume of the Continental Shelf between latitudes 22°S and 24°S is of the order of 300 cubic miles.) While systematic measurement of the stream loads has not been made, measurement of water at the mouth of the Fitzroy during flood has yielded mud loads of 1,000 p.p.m. The average annual load would be considerably less. A large proportion of the suspension in the streams is flocculated in the tidal reaches and spread along the Near-Shore Zones near the river mouths. The coastal islands provide an abundant source of wind-blown sand which adds to the complexity of the near-shore facies.

Hydrography

Water movement in the Great Barrier Reef region is not well understood and data on current behaviour is very limited. Surface movements are strongly influenced by the wind systems and tidal changes. The prevailing wind from November to April is the south-east trade whose mean velocity off-shore approximates 8 m.p.h. Higher velocities (20 to 30 m.p.h.) are frequent and in this range sea conditions become too dangerous for small craft. During this same period atmospheric depressions develop over the Coral Sea and move westward causing cyclonic conditions along the Queensland seaboard. In the winter months (May–October) both the cyclonic pattern and south-east trades diminish and northerly and westerly winds may develop. The effect of the summer wind system is to produce strong easterly and south-easterly swells with a general movement of surface water to the west and north-west. In the winter months the weaker winds cause little surface movement. Tidal currents are significant throughout the area; velocities of 1 to 3 m.p.h. develop on the ebb and flood tides in the Near-Shore Zone and reef areas. No values of current velocities are available for the shelf regions outside of the reef areas, and little is known of the sub-surface and bottom currents. However, the regional gradients of the area, together with the distribution of the sediment type, give some indication of possible bottom current direction. There appears to be an overall easterly to south-easterly movement in the shelf regions. Smaller eastward movements appear to be active through the Capricorn-Bunker Groups. In the Southern Shelf Embayment bottom currents probably flow south-eastward down the gradient. The effect of the low east-west rises which extend across the shelf is difficult to assess.

LITHOFACIES ANALYSIS AND INTEGRATION

The lithofacies pattern has been established on granulometric, gross chemical, and gross lithological analysis. Detailed mineralogical, chemical, and petrographic studies are still in progress and their results will undoubtedly refine the present interpretation but they should not lead to major alterations in the basic pattern.

Granulometric analysis

The results of granulometric analysis have been presented in Figures 2, 3, and 4, in the form of modal, sorting, and sand/mud distribution patterns. All three patterns are similar and reflect the controlling influence of bottom topography, location of source, and water movement.

From the modal map (Fig. 2), it is evident that the very coarse sands are concentrated on the Marginal Shelf—the Swain Reefs and the Capricorn-Bunker reefs. Near-shore banks and beaches provide small concentrations, but reefs are the main source of the very coarse material (i.e. > 1.0 mm). The coarse and medium grades are most

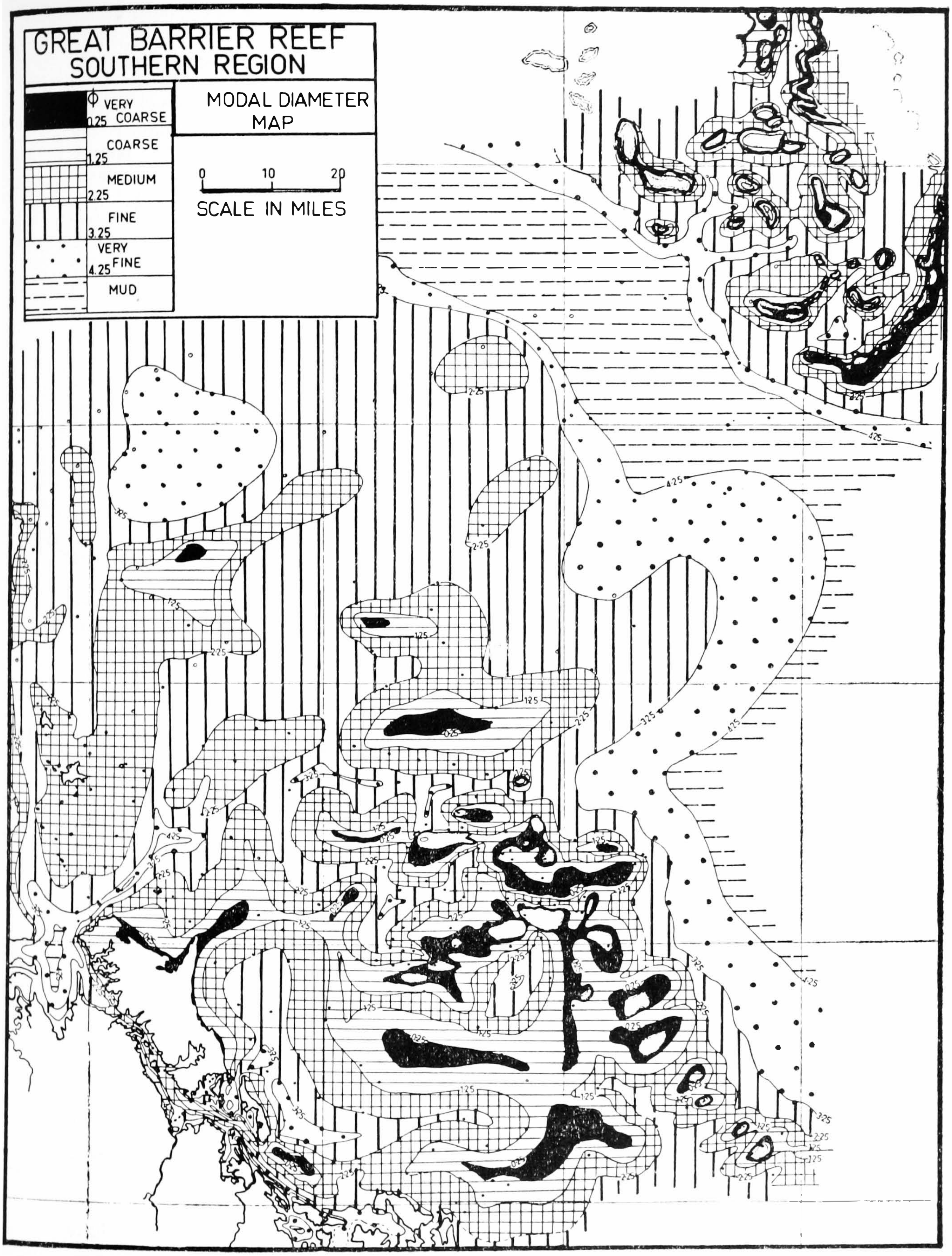

FIG. 2.—Modal diameter distribution.

abundant on the Inner Shallow Shelf, 4–10 miles from the shoreline. Sediments in this region are derived mainly from the coastal sand dunes and rarely exceed the .5 mm grade. The distribution of fine and very fine sand grades is more widespread. They are concentrated in the Near-Shore Zone—bays and harbours, channels and estuaries—inter-reef depressions, and along the borders of the Capricorn Channel. Many sources contribute to these fine grades—reefs, coastal dunes, stream loads—thus accounting for their occurrence in such a diversity of environments.

Muds occur in three main areas—the near-shore mangrove belt, in the Fitzroy mouth, and in the Capricorn Channel. In all three cases, the mud is mainly of terrigenous origin. Carbonate mud occurs in the inter-reef depressions, generally intermixed with coarser detritus, and in parts of the Capricorn Channel.

The sorting pattern of Figure 3 shows that good sorting develops in areas of high energy, provided abundant source material does not occur in the same zone. Best sorting is found in the near-shore sand banks (inside the 20-fathom line), and in the southern end of the Bunker Group where reef density is lower and where there is little protection from the heavy south-east swell and storm waves. Poorest sorting occurs in the inter-reef and back-reef areas which are protected from severe wave agitation and which are close to the prolific source of reef detritus. Constant destruction by wave action on the windward side provides an abundant supply of reef detritus, much of which is swept into the lee of the reef and deposited before sorting agencies can become effective. Another region of poor sorting is found where terrigenous and reef detritus are intermixed—i.e. at the overlap of terrigenous and reef facies. The areas of moderate sorting are found in the Capricorn Channel and immediately surrounding the reefs.

The sand/mud ratio map (Fig. 4) is consistent with the modal diameter pattern described above. Cleanest sands occur in the vicinity of the reefs and the near-shore banks, while very dirty, muddy sands are found in the protected bays. Muds and fine muddy sands cover the deeper part of the Southern Shelf Embayment, a large portion of the Inner Shallow Shelf north of the Capricorn Group, the near-shore mangrove belt, and parts of bays and river mouths. The areas of mixing of reef and terrigenous sediment are moderately clean west of the Capricorn-Bunker Groups, but muddier to the west of the Swains. In the overall pattern, a striking feature is the contrast between the Inner Shallow Shelf and the Southern Shelf Embayment. The Inner Shelf sediments are closer to both terrigenous and reefal sources and are subject to more reworking in their shallow waters. The Southern Shelf Embayment is more distant from land and deeper, and therefore more favourable for the deposition of finer sediment.

With all three parameters there are distribution trends which appear to be related to bottom topography, water movement and supply. A dominant trend is found parallel with the shoreline—in general sorting improves in the shallower depths, grain size decreases away from the source, and mud fractions increase seaward. Important cross trends disrupt this shoreline parallelism. Most evident are the east-north-east zone off Water Park, the east-north-east zone from Cape Capricorn to North Reef, the Polmaise-Sykes Reef and Capricorn inter-reef trends, the Port Curtis trend and the easterly zone of Bustard Head. Topographic highs are partly responsible for the Cape Capricorn, Polmaise-Sykes Reef, and Bustard Head zones. Along all three, coarser clean sands are predominant, and except for the Cape Capricorn-North Reef zone, sorting is good. The poorer sorting of the latter is due to intermixing of terrigenous and reef detritus and the protection of the Capricorn Group. Topographic depressions are partly responsible for the Capricorn inter-reef and Port Curtis trends. Fine, poorly sorted, dirty sediments occur in the deeper protected waters of these zones.

Closely related to bottom topography is the distribution of the reefs. They have grown on bottom swells or have produced topographic highs through their growth. As well as their topographic influence, they exert an important source influence,

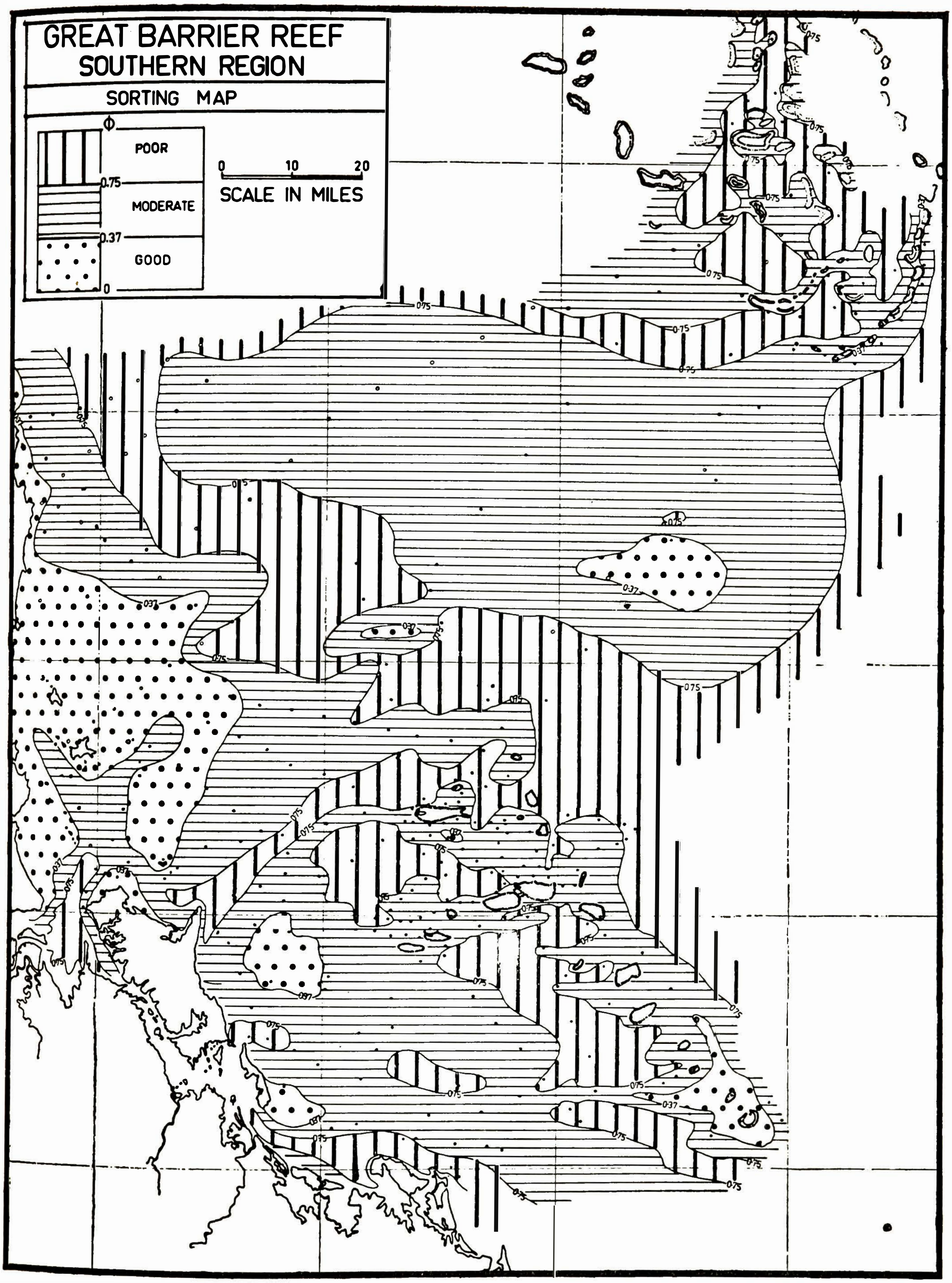

FIG. 3.—Sorting patterns.

and their proximity to depositional areas determines the sorting and grade of the sediment that is deposited. This is especially significant in the intermediate facies where terrigenous and reef detritus are intermixed. Here, the reef detritus superimposes on the land sediment a granulometric pattern that may be markedly different from that developing by normal near-shore processes. This conflict of trends is seen in the increasing sand grade with distance from shore and decline in sorting due to the introduction of material from new sources.

Water movement is also significant, particularly with respect to the sand/mud distribution and sorting processes. The main water movements are related to stream discharge, long-shore currents, tidal currents, and the normal easterly movement down the gentle shelf gradient. Stream discharge is responsible for localizing flocculation of mud, much of which is trapped in the mangrove zone; for the building-up of well-sorted sandbanks marginal to the main channels; and for the deposition of poorly sorted, muddy sands in the deeper parts of the river mouths. Long-shore currents are important in the northward movement of sands which have been eroded from the coastal dunes, most of which are of aeolian origin. This important source of sediment contributes sand grades that have been determined initially by wind competency and thus are somewhat finer than grades which one might expect from stream discharge. Tidal currents have important scouring effects in restricted channels, such as are found behind the coastal islands and between reefs. In general their effect is quite local. The normal down-gradient movement of water is mainly responsible for the dominant shoreline parallelism of sedimentary trends. However, because the gradient is so slight such movement must be slow, and furthermore, it is opposed by the surface drift, the prevailing wind, and oceanic circulation.

Granulometric parameters all respond to the same influences, although to different degrees. However, since they result in similar distribution patterns, it has been possible to relate these patterns to the influencing factors. It is also possible to relate the patterns one to another. In general, good sorting occurs in the medium to fine sand grades (Inner Shallow Shelf, southern end of Bunker Group) although in the Swain Reefs which represent a higher energy environment, coarse and very coarse grades are well sorted. Poor sorting is typical of the coarse and very coarse, dirty sediments in back-reef and reef-shoal areas, and of fine to very fine modal groups in the inter-reef depressions. Generally however the coarser sediments are fairly clean.

Acid solubles analysis

Figure 5 is a plot of the percentage of acid solubles in the sediments. It provides an immediate separation of three major sedimentary groups, viz. the carbonates with less than 20 per cent insoluble content, the terrigenous with more than 40 per cent insolubles, and the intermediate or mixed sediments with 20–40 per cent insolubles. The main carbonate facies occurs in two areas—the Swain Reefs and the Capricorn-Bunker Groups. Contamination of the carbonate facies by terrigenous material is slight in the Capricorn-Bunker Groups and appears to be negligible in the remote Swain Reefs. The main terrigenous facies extends from the shoreline, seaward around the northern and southern extremities of the Capricorn and Bunker Groups, and down the western and central parts of the Southern Shelf Embayment. The mixed facies occupies a large part of this Embayment and the border zone between the Inner Shallow and Western Marginal Shelves.

Distance from source is the major controlling factor in the distribution of soluble material. Water movement and bottom topography modify this distribution. The overall eastward movement of water from shore and down the gradient of the Capricorn Channel is reflected in the linear tongues of terrigenous material that extend eastward from shore and south-east into the Capricorn Channel. The location of these terrigenous sediment tongues is controlled mainly by the location of river discharge, reefs, reefal banks, and other topographic rises.

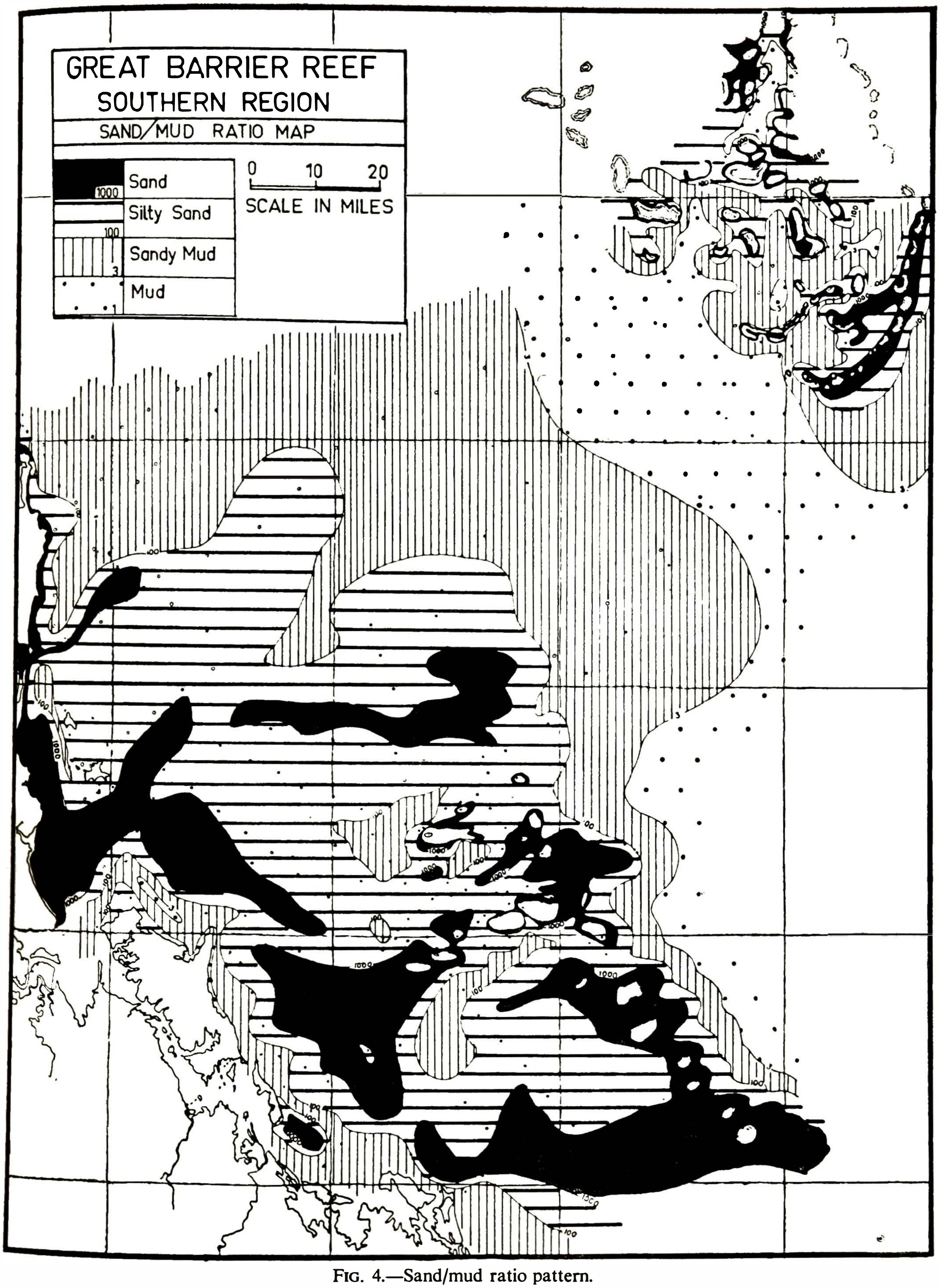

Fig. 4.—Sand/mud ratio pattern.

Lithofacies integration

Integration of the chemical and granulometric data permits the recognition of three major facies groups—terrigenous, carbonate, and intermediate or mixed. Further subdivision of these is possible into eleven sedimentary types, the distribution of which is shown in Figure 6.

The terrigenous facies is found in the near-shore areas, adjacent parts of the Inner Shallow Shelf and in two belts across the Western Marginal Shelf south of the Bunker Group and north of the Capricorn Group where a tongue penetrates the western fringe of the Southern Shelf Embayment. The carbonate facies is limited to the inter-reef and adjacent areas of the reef provinces. The region between these two facies is occupied by the intermediate or mixed facies. It extends in a zone along the Inner Shallow Shelf-Western Marginal Shelf border, in two arms north and south of the Capricorn-Bunker reefs, throughout the Southern Shelf Embayment except for its fringe areas, and the outer part of the Continental Slope off the Capricorn-Bunker Groups. The eleven sedimentary types are subdivisions within the above facies based on granulometric differences.

LITHOFACIES CONTROLS

Preliminary work indicates that normal physical forces are acting on and controlling the pattern of sediment distribution. The basic factors are: (1) The volume and kind of material supplied; (2) the competency, capacity, and direction of the transporting medium; (3) the environmental energy permitting deposition, reworking, or winnowing of the sediments. The sediment is derived from two major sources—the land mass and the reefs. The land source may be subdivided into the continental and the coastal regions. The continental source is adding muds mainly to the western part of the area via large rivers, while the coastal region provides fine, wind-blown sand from the dunes to the western fringe of the area. Mud from the land is flocculated in the tidal reaches and protected bays—it forms the extensive mud flats which occur behind the coastal islands. Some of this material is also carried further seaward. Sand accumulations are rare in the lower reaches of the streams, but large deposits occur in the wider estuaries as banks, where swift tidal currents scour the finer materials, and in the adjacent areas of the Inner Shallow Shelf. Consideration of the modal diameters of samples from the banks to the north and south of Curtis and Facing Islands shows that they are in the range of 0.125–0.088 mm. This range is normal for the dune sands and is generally finer than that of the sands further off-shore. The implication is that a considerable part of the coarser sediment in the near-shore area and near estuaries could have been derived not directly from the land through stream erosion, but through transportation of coastal sands by wind and long-shore currents over distances of many hundreds of miles. If this is valid, then the contribution of the larger river systems to the coarser sediment accumulations may be far less than appears. The rivers, in fact, probably provide the bulk of the argillaceous sediment and very little of the arenaceous. Beyond the coastal islands, however, the degree of mud flocculation is less, and scouring by waves and currents prevents much mud deposition. Organic reef detritus is carried landward by swell and tidal currents. It mixes with the seaward moving terrigenous material on the outer fringes of the Inner Shallow Shelf and on the Western Marginal Shelf to the north and south of the Capricorn-Bunker reefs, to form the coarser grades of the intermediate facies. In the Southern Shelf Embayment finer terrigenous clays settle with fine carbonate muds, in the deeper, quiet water of the Embayment. They form the finer grades of the mixed facies. On the eastern flank of the Embayment the increased distance from land and the proximity of the Swain Reefs causes the carbonate facies to reappear. In the reef areas carbonates are wholly predominant. The acid-solubles and lithofacies maps suggest that currents are transporting terrigenous materials around the reef areas. Bathymetry would suggest that transportation should also occur through the

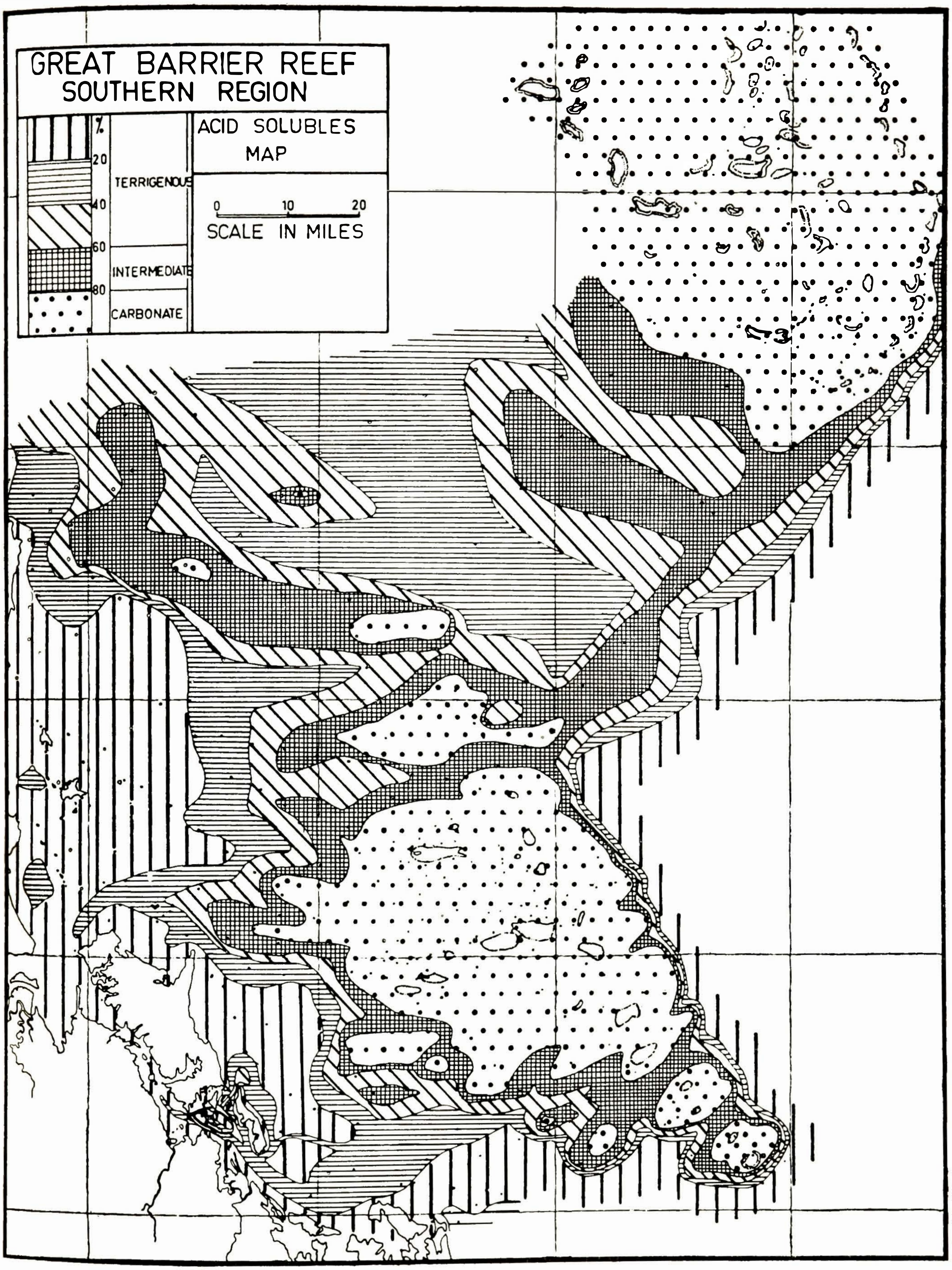

FIG. 5.—Acid solubles map.

Capricorn-Bunker reef area. However, as less than 4 per cent insoluble is found in the reef area, one must conclude that either (1) the terrigenous material is passing around the reefs or (2) production of reef detritus is so voluminous as to dilute and almost obscure the terrigenous material.

Although a trace of terrigenous material is present in the Capricorn-Bunker reef area, almost none finds its way into the more distant Swain Reefs. Within the Capricorn-Bunker reef area sedimentary types are distinguished mainly on size and sorting of the sands. The coarsest and best-sorted sands occupy the exposed marginal areas while the finer but less-sorted materials are found in the sheltered interior and lee parts of the province. The Swain Reefs sediments, however, are generally moderately sorted, coarse, and very clean, similar to those of the unprotected areas of the Capricorn-Bunker Groups.

The Continental Slope east of the Capricorn-Bunker Groups is a zone of poor sorting as reef-derived sands mix with Embayment-derived muds. In the upper part of the slope the carbonate sand dominates, making this region part of the poorly sorted carbonate facies. This gives way to the influx of Embayment muds with depth and this part of the slope belongs to the poorly sorted, sand and mud, intermediate facies.

As no samples were collected from the Coral Sea Continental Borderland little can be said of the sediments there. As one approaches the Borderland from the reef areas, the carbonate sands are replaced by terrigenous and carbonate muds. It seems reasonable to assume that this trend continues at least to the adjacent areas of the Borderland.

CONCLUSIONS

From the present work a sediment distribution pattern and the general factors responsible for it have been deduced for the southern region of the Great Barrier Reef. Purely terrigenous materials are restricted to the Near-Shore Zone, the Inner Shallow Shelf, Western Marginal Shelf (north and south of the areas of reef growth), and a small area on the western flank of the Southern Shelf Embayment. These sediments are distributed by currents which are influenced by bottom topography, wind, and swell. Carbonate lithofacies are restricted to regions surrounding the reefs. On the marginal shelves and the upper fringe of the Continental Slope carbonate detritus is distributed into adjacent terrigenous materials producing a mixed facies.

ACKNOWLEDGMENTS

The survey of the southern region of the Great Barrier Reef was made possible through the generous assistance of the Standard Oil Company of New Jersey and its subsidiary the Jersey Production Research Company. All laboratory research was conducted in the Department of Geology, University of Queensland. Marine work was carried out from the trawler "Emperor II" under the command of Mr. R. Shields.

To all those associated with this project the authors express their sincere gratitude.

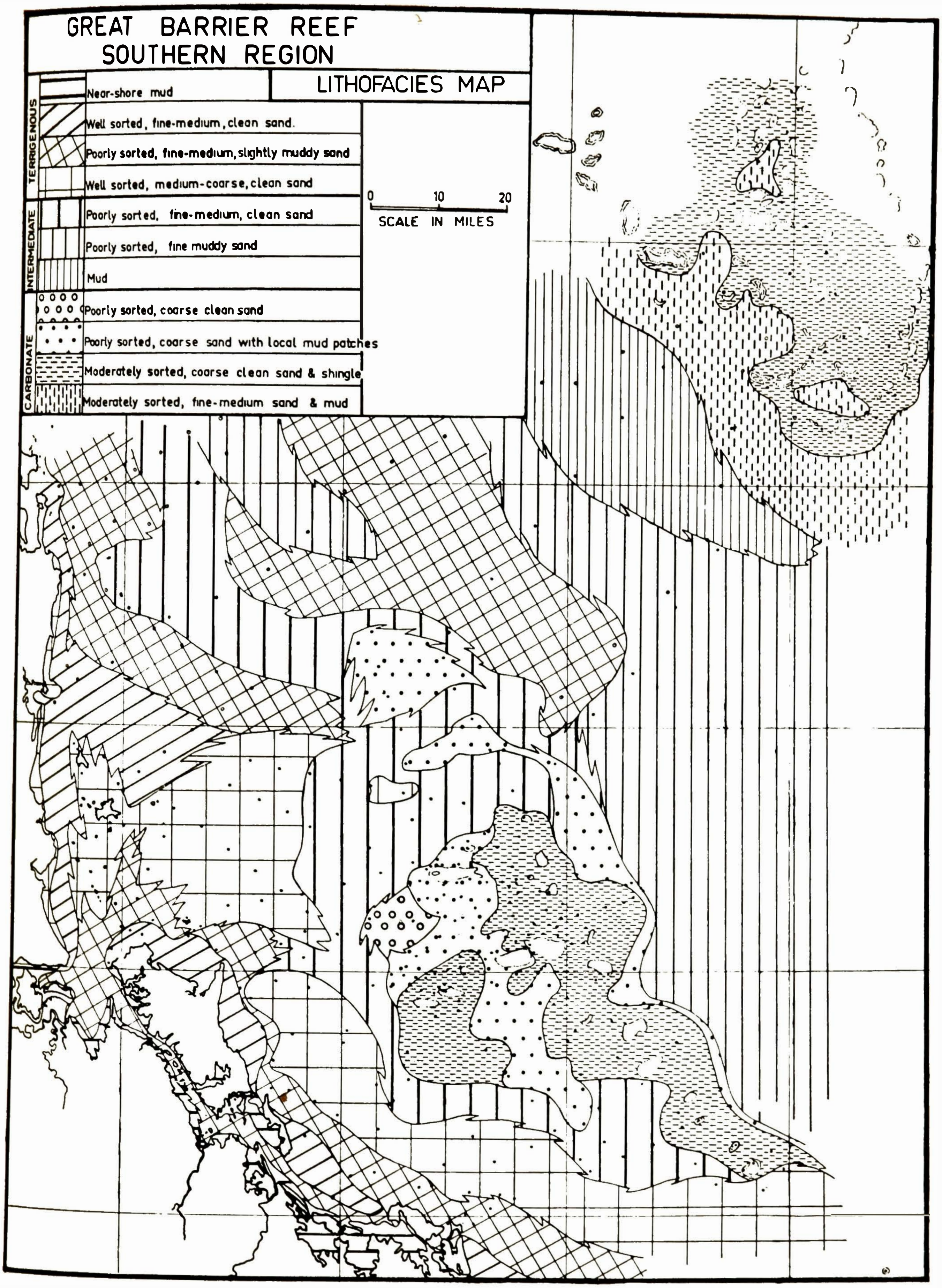

FIG. 6.—Lithofacies map, southern part of the Great Barrier Reef.

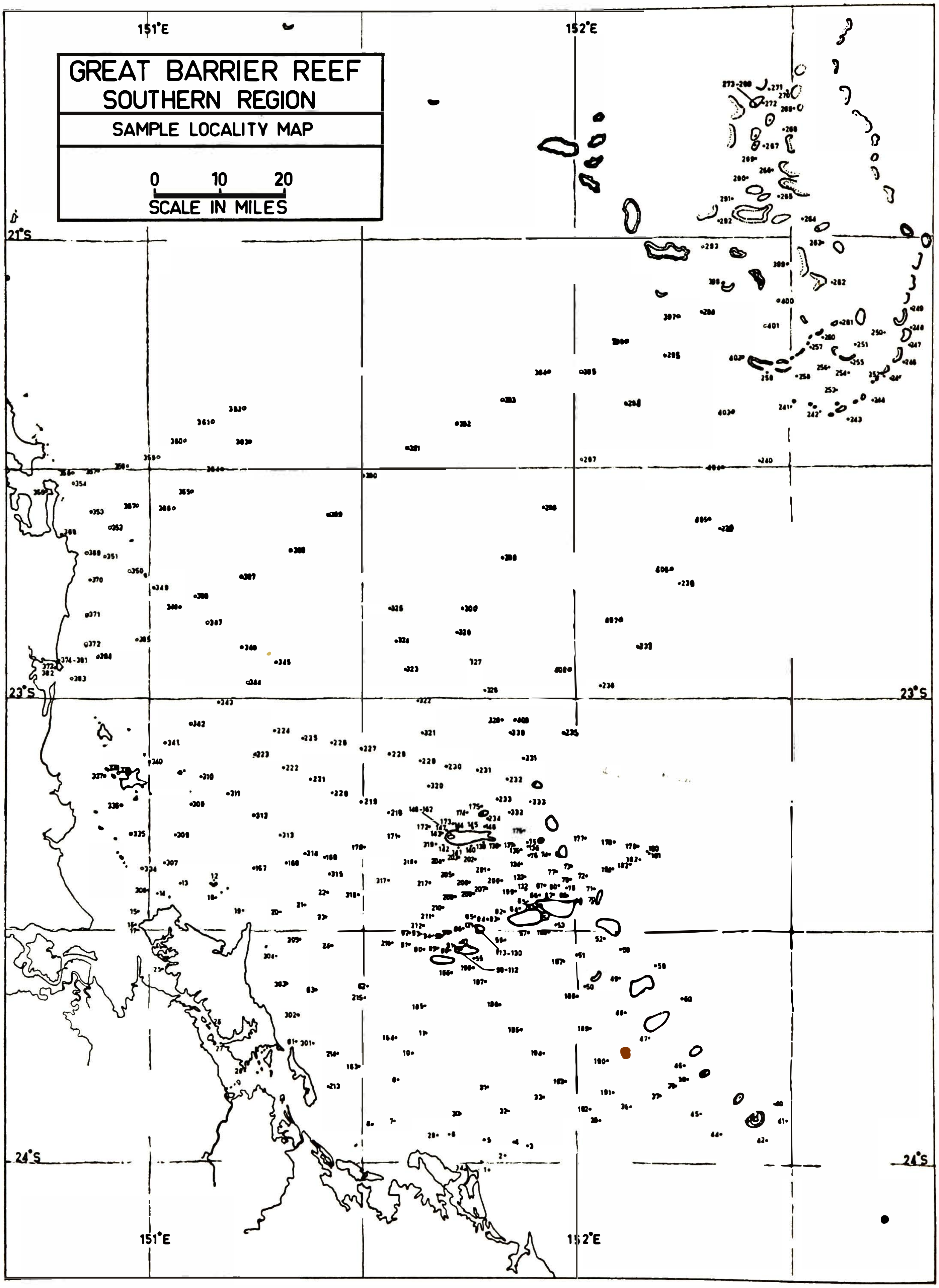

FIG. 7.—Sample locality map of the southern region of the Great Barrier Reef.

APPENDIX I—WATER MEASUREMENT

G.B.R. Sample Number	Depth (Fathoms)	pH	Salinity	Temp.
1	0	—	34.8	26.0
	7		34.8	26.0
	15		34.8	26.0
2	0	8.0	34.8	25.9
	8	8.0	34.8	25.9
	16	8.0	34.8	25.9
3	0	—	34.9	25.9
	7	—	34.9	25.9
	15	8.4	34.9	25.9
4	0	—	34.8	25.9
	7	—	34.9	25.9
	15	7.5	34.9	25.9
5	0	7.5	34.9	25.9
	8	—	34.9	25.9
	16	7.9	34.9	25.9
6	0	7.4	34.8	26.1
	7	—	34.8	26.1
	14	7.7	34.9	26.2
7	0	7.8	34.7	25.9
	5	—	34.7	25.9
	10	8.0	34.7	25.9
12	0	7.4	34.8	26.2
	5½	7.4	34.9	26.4
14	0	—	35.1	26.5
	5½	—	35.1	26.5
15	0	—	34.9	26.5
	3½	—	34.9	26.5
16	0	—	34.6	26.5
	6	—	34.6	26.5
17 (2.00 p.m.)	0	—	33.4	27.5
	4	—	34.3	27.0
17 (5.15 p.m.)	0	—	33.4	27.5
	5	—	34.3	27.0
17 (9.00 p.m.)	0	—	33.8	26.8
	4	7.5	34.8	26.6
17 (6.00 a.m.)	0	—	32.2	26.3
	4	—	34.8	26.6
18	0	—	34.3	26.2
19	0	—	34.4	26.2
20	0	—	34.8	26.2
21	0	—	34.8	26.3
22	0	—	34.8	26.5
25	0	—	25.2	25.7
	5	—	32.8	26.1
26	0	—	22.0	26.1
	4	—	23.6	26.1
27	0	—	23.0	25.8
	5	—	24.3	25.8
28	0	—	25.6	25.8
	10	—	27.4	26.4
34	0	—	30.4	25.4
	2½	—	32.5	25.4
38	0	—	34.5	25.6
39	0	—	34.5	25.9
40	0	—	34.5	26.8
41	0	—	34.5	26.8
	21	—	34.5	25.5
42	0	—	34.5	25.9
43 (6.45 p.m.)	0	—	34.5	26.2
	4½	—	34.4	26.2
43 (9.15 p.m.)	0	—	34.5	26.2
	4½	—	34.5	26.2
43 (6.00 a.m.)	0	—	34.5	25.7
	4½	—	34.5	25.7
44	0	—	34.6	25.7
	24	—	34.7	25.4
45	0	—	34.6	25.7
46	0	—	34.6	25.7
	24	—	34.7	25.4
47	0	—	34.6	25.7
48	0	—	34.6	25.7
	24	—	34.6	25.6
49	0	—	34.5	26.1
50	0	—	34.5	25.3
51	0	—	34.6	26.4
	25	—	34.6	25.9
53	0	—	34.7	26.2
	23	—	34.75	26.0

— Not determined.

G.B.R. Sample Number	Depth (Fathoms)	pH	Salinity	Temp.
55	0	—	34.7	26.0
56	0	—	34.6	26.4
57	0	—	34 6	26.2
	19	—	34.7	26.2
64 (10.55 a.m.)	0	8.30	34.6	25.4
	6½	8.25	34.6	25.0
64 (6.00 p.m.)	0	—	34.7	25.1
	7½	—	34.7	25.4
64 (8.15 a.m.)	0	—	34.7	25.2
	7½	—	34.7	25.0
87	0	7.8	34.6	25.2
	12	7.9	34.6	25.2
97 (5.15 p.m.)	0	8.3	34.6	25.2
	6½	8.3	34.6	25.2
97 (8.00 a.m.)	0	8.3	34.5	25.0
	6½	8.25	34.5	25.0
139	0	8.15	34.5	25.2
	20	8.3	34.5	25.2
143	0	8.2	34.5	25.2
	8	8.3	34.5	25.2
167	0	—	35.0	24.3
	24	—	35.1	24.1
177	0	8.15	35.0	25.4
	26	8.0	35.0	25.2
178	0	—	35.0	25.4
179	0	—	35.0	25.5
	60	8.0	35.1	25.2
193	0	8.25	35.2	25.3
	20	8.2	35.5	25.0
200	0	8.2	35.4	25.0
	20	8.2	35.5	25.0
237	65½	8.0	—	—
238	60	8.0	—	—
240	56	8.2	—	—
245	27	8.5	—	—
252	0	8.4	—	—
	20	8.4	—	—
260	0	8.1	—	—
	16	8.1	—	—
272 (7.00 p.m.)	0	8.0	—	—
	20	8.0	—	—
272 (7.00 a.m.)	0	7.95	—	—
	20	8.1	—	—
296	0	8.05	—	—
	53	8.00	—	—

APPENDIX II—SEDIMENT PARAMETERS

G.B.R. Sample Number	Per cent Insoluble in HCl	PHI Sorting Coefficient	Depth in Fathoms
1	75.5	0.8	15
2	89.3	0.75	16
3	86.3	0.45	15½
4	93.9	0.45	15
5	89.8	0.50	16½
6	83.9	0.52	14
7	69.7	0.65	10½
8	70.9	0.66	8
9	79.1	0.60	11
10	27.5	0.68	14
11	49.7	0.60	16
12	62.5	0.25	5½
13	80.7	0.82 (sand fraction)	11
14	83.0	0.37	5½
15	79.2	0.39	3½
16	81.5	0.39	6
17	—	—	4½
18	83.0	0.49	10½
19	68.2	0.87	7½
20	26.7	1.09	16
21	16.6	0.53	16½
22	43.6	0.62	16½
23	23.0	0.45	16½
24	76.3	0.36	15
25	88.2	0.68	5½
26	38.3	0.85	4
27	88.4	0.61 (sand fraction)	6

— Not determined.

G.B.R. Sample Number	Per cent Insoluble in HCl	PHI Sorting Coefficient	Depth in Fathoms
28	58.5	0.62	10
29	62.9	0.84	12
30	76.7	0.41	16
31	74.5	0.80	16
32	90.2	0.42	16
33	94.0	0.42	16
34	85.1	0.72	2½
35	37.6	0.76	20
36	23.6	0.98	23
37	80.6	0.29	22½
38	4.9	0.74	22½
39	1.4	0.71	13
40	6.4	0.62	31
41	91.2	0.49	26
42	87.5	0.32	29
43	10.2	0.60	4½
44	54.8	0.47	24
45	50.4	0.74	19
46	6.3	0.72	24½
47	13.7	0.93	28
48	3.7	0.64	24
49	8.3	0.82	29
50	3.7	0.85	26
51	7.9	0.87	31
52	2.6	0.88	28
53	2.8	0.96	23½
54	1.3	0.65	14
55	0.5	0.51	14
56	1.8	0.54	15
57	0.4	0.79	19
58	5.2	0.72	34
59	1.4	0.49	26
60	—	0.51	32
61	52.2	1.46	8
62	78.1	0.42	14
63	89.8	—	10½
64	0.0	0.80	8½
65	0.4	0.82	10
66	0.5	0.62	15
67	0.0	0.36	13½
68	0.2	0.27	9
69	0.0	0.47	6½
70	0.0	0.76	8
71	3.0	0.60	17½
72	4.2	0.75	26
73	5.3	0.84	25
74	4.4	0.61	4½
75	3.4	0.48	13
76	3.7	0.63	20½
77	3.0	0.61	24
78	4.5	0.75	24½
79	4.4	0.81	19½
80	1.8	0.64	19
81	0.6	0.70	21
82	0.1	0.89	14
83	0.6	0.46	13
84	1.5	0.51	16
85	0.2	0.79	16
86	1.7	0.36	16
87	0.9	0.58	12
88	0.5	0.37	12
89	0.4	0.60	16
90	0.6	0.49	9½
91	2.3	0.54	12
92	3.4	0.98	16
93	2.3	1.28	16
94	1.0	0.58	16
95	1.7	0.58	16½
96	1.1	0.71	17
97	1.7	0.89	6
98	3.4	0.58	Masthead Reef
99	1.5	0.50	
100	1.6	0.98	
101	1.0	1.18	
102	1.9	1.05	
103	1.9	0.95	
104	1.1	1.13	
105	2.0	1.39	
106	0.9	0.86	
107	1.1	1.10	
108	0.7	0.33	
109	0.8	0.45	
110	—	—	
111	—	—	
112	1.2	0.23	Erskine Reef
113	0.3	0.24	
114	0.8	0.35	
115	0.8	0.31	
116	0.1	0.35	
117	0.5	0.48	
118	0.1	0.40	
119	0.6	0.38	
120	0.7	0.44	
121	2.4	0.46	
122	2.1	0.36	
123	1.6	0.32	
124	1.8	0.28	
125	1.7	0.18	
126	2.1	0.32	
127	2.1	0.42	
128	—	—	
129	—	—	
130	—	—	
131	0.6	0.68	
132	0.7	0.75	20½
133	0.8	0.69	24
134	0.3	0.65	20
135	1.0	0.68	8½–12
136	0.1	1.0	12
137	0.0	0.74	9½
138	0.1	0.85	20
139	1.4	0.64	20
140	0.7	0.45	14
141	1.2	0.55	10
142	0.0	0.66	15
143	2.3	0.70	8
144	1.3	0.76	—
145	1.6	0.72	6
146	0.6	—	11

— Not determined.

G.B.R. Sample Number	Per cent Insoluble in HCl	PHI Sorting Coefficient	Depth in Fathoms
147	0.0	0.81	5
148	1.3	0.48	North West Reef
149	1.1	1.06	
150	1.8	1.14	
151	0.0	0.69	
152	0.0	0.60	
153	0.0	1.07	
154	0.0	0.25	
155	0.0	0.28	
156	0.0	0.79	
157	0.0	0.86	
158	0.1	0.76	
159	0.2	1.00	
160	—	—	
161	—	—	
162	—	—	
163	81.2	0.69	12
164	43.7	0.52	14
165	2.6	0.45	11½
166	3.1	0.47	21
167	57.6	0.45	17½
168	55.0	0.59	17
169	19.3	0.79	17
170	37.3	0.70	18
171	10.2	0.73	19
172	2.1	1.08	20
173	2.6	0.84	20
174	1.9	0.84	19½
175	2.3	0.78	24
176	—	—	6
177	0.9	0.96	26½
178	2.5	0.72	34
179	50.6	0 78	72
180	67.6	0.92	104
181	—	—	116
182	6.6	0.88	52
183	2.1	0.53	44
184	0.7	0.52	26
185	1.2	0.65	7
186	2.1	0.64	22½
187	4.0	0.70	24
188	2.3	0.68	18
189	4.5	1.08	24
190	38.9	0.92	24
191	12.4	0.63	22
192	35.1	0.86	19
193	13.3	0.82	20
194	34.1	0.47	20
195	6.9	0.52	19½
196	4.0	0.50	20
197	4.8	0.84	21
198	4.1	1.01	22
199	1.5	0 86	20
200	1.9	0.51	20
201	0.2	0.56	18½
202	1.5	0.32	20
203	1.2	0.74	21
204	2.0	0.64	19
205	2.3	0.97	19
206	3.1	0.99	19
207	1.4	0.82	18
208	1.2	0.89	19
209	0.8	0.74	18
210	1.0	0.49	17
211	4.6	0.74	17½
212	4.1	0.36	16
213	94.1	0.23	4½
214	85.6	0.68	11½
215	86.1	0.39	13½
216	15.3	0.55	17½
217	2.5	0.98	18
218	31.0	0.82	20
219	29.7	0.73	20
220	29.9	—	19½
221	59.8	0.43	19
222	69.8	0.44	20
223	80.7	0 30	18
224	73.5	0.30	18
225	58.6	0.48	20
226	34.0	0.73	20
227	37.0	0.48	21
228	49.6	0.76	22
229	51.7	0.43	24
230	35.0	0.61	25½
231	32.3	0.62	26
232	4.0	0.89	28
233	15.8	0.84	26
234	1.0	0.70	8½
235	9.1	1.02	35
236	20.6	0.79	66
237	24.6	0.74	65½
238	38.4	0.28	60
239	33.7	0.47	48
240	19.9	0.52	56
241	7.3	—	57
242	2.4	0.65	37½
243	0.9	0.48	33
244	—	—	24
245	1.4	0.42	27
246	2.1	0.55	28
247	2.5	0.73	29
248	—	—	29
249	—	—	18
250	1.0	0.87	20
251	1.0	0.55	29
252	0.7	0.31	20
253	1.7	0.76	28
254	0.7	0.62	27½
255	1.4	0.73	31
256	1.5	0.95	33
257	1.5	0.67	32
258	3.5	1.03	48
259	2.0	1.14	48
260	0.0	0.96	16
261	0.0	0.45	28
262	0.3	0.94	23
263	0.0	0.95	32
264	0.3	0.79	33
265	0.0	0.97	33
266	0.0	0.88	30

— Not determined.

G.B.R. Sample Number	Per cent Insoluble in HCl	PHI Sorting Coefficient	Depth in Fathoms
267	0.0	1.29	23
268	0.0	0.49	32
269	0.0	1.08	27
270	0.0	0.83	32
271	0.4	0.74	31
272	0.0	0.76	20
273	0.0	0.53	Gannet Cay Reef
274	0.0	0.74	
275	0.0	0.65	
276	0.0	0.90	
277	0.0	0.30	
278	0.0	0.24	
279	0.0	0.29	
280	0.0	0.31	
281	0.0	0.40	
282	0.0	0.39	
283	0.0	0.54	
284	0.0	0.55	
285	0.0	0.50	
286	0.0	0.45	
287	0.0	0.39	
288	—	—	
289	2.5	0.69	32
290	3.2	0.80	36
291	2.0	1.03	18
292	0.6	0.45	19
293	1.6	0.53	44
294	6.4	0.57	58
295	13.3	0.55	56
296	28.5	0.78	53
297	32.6	0.60	48
298	43.7	0.58	40
299	77.3	0.49	34
300	70.4	0.64	34
301	82.5	0.89	9½
302	87.1	0.47	8½
303	86.5	0.41	9
304	83.1	0.43	9½
305	73.9	0.38	15
306	67.2	1.13	13
307	84.4	0.55	9½
308	91.3	0.41	13
309	92.8	0.34	13
310	83.3	0.54	15½
311	87.3	0.34	14
312	74.1	0.38	15
313	81.2	0.43	16
314	49.9	0.57	16
315	11.9	0.63	16
316	13.2	0.67	17
317	2.3	1.06	18
318	2.0	1.07	19
319	1.2	0.73	19
320	26.7	0.80	25
321	3.8	0.79	19½
322	31.9	0.76	25
323	59.7	0.33	27
324	10.8	0.78	26
325	33.4	0.90	30
326	—	—	12
327	39.2	0.76	28
328	—	—	19
329	0.0	0.60	10½
330	15.2	0.80	28
331	31.3	0.58	32
332	0.9	0.76	24

— Not determined.

THE LAVA SUCCESSION NEAR SPICER'S PEAK

GEOLOGICAL MAP
of the
SPICER'S PEAK REGION