THE SIGNIFICANCE OF TWO CONTRASTING SEDIMENTARY ENVIRONMENTS (THE FRINGING CORAL REEF AND THE TIDAL MUD FLAT) PRESENTLY IN JUXTAPOSITION ALONG THE SOUTHWESTERN SHORE OF MORETON BAY, QUEENSLAND.

by **P.G. Flood**

(with 2 Text-figures, 1 Table, and 6 Plates)

ABSTRACT. Fringing coral reefs are developed adjacent to the islands within Moreton Bay, near Dunwich on the western side of North Stradbroke Island, and along the southwestern shores of the bay between Point Halloran and Wellington Point. Between Wellington Point and Cleveland Point reef growth is almost continuous for 10 km, but rarely exceeds 5 m in thickness. This reef began to develop approximately 7500 years B.P. upon a seaward-sloping laterite platform. Coral growth did not keep pace with rising sea-level. Portions of the reef may have reached the intertidal zone about the same time as those reefs at Mud Island where uranium series dates of 4100 to 6000 B.P. have been obtained. Subsequently the back-reef area has been filled with terrigenous and bioclastic sediments. A distinctive tidal flat zonation has developed. Mangroves have developed in relatively recent times, having firstly colonized the upper intertidal surface of the reefs (north of Empire Point) or the landward side of beach ridges (shores of Raby Bay). Organic mud produced by the mangroves severely inhibits coral growth and the intertidal surface of the reef now consists of dead *Acropora*, whereas living corals (Faviidae) are restricted to the subtidal areas. Seaward progradation of the mangroves is very limited, however, landward extension is evident in some places.

INTRODUCTION

The area between Cleveland Point and Wellington Point displays a variety of geological features of both academic and economic interest. Fringing reefs which are presently dredged by the Queensland Cement and Lime Company provide a source of lime for the Darra Cement Works. These reefs which consist of a framework of predominantly dead *Acropora* spp. must have formed when conditions were markedly different from those of today, for the genus *Acropora* is now unable to flourish in the muddy environment at this location.

Tidal mud flats are developed adjacent to the mainland. These flats exhibit prominent biotic, hydrodynamic, and sedimentological zonation similar to those described in Ginsburg (1975). Several distinct communities which are associated with a prograding sequence of sediments may be recognised. The history of sedimentation during Holocene times indicates a transgressive phase followed by a contemporary regressive phase. The

Pap. Dep. Geol. Univ. Qd, 8(2): 44 – 63 , pls 1-6, October 1978.

regressive phase is not necessarily related to a recent eustatic sea level fall but may be explained by progressive soil formation and sediment accretion causing a gradual raising of base level. This is indicative of land-building processes.

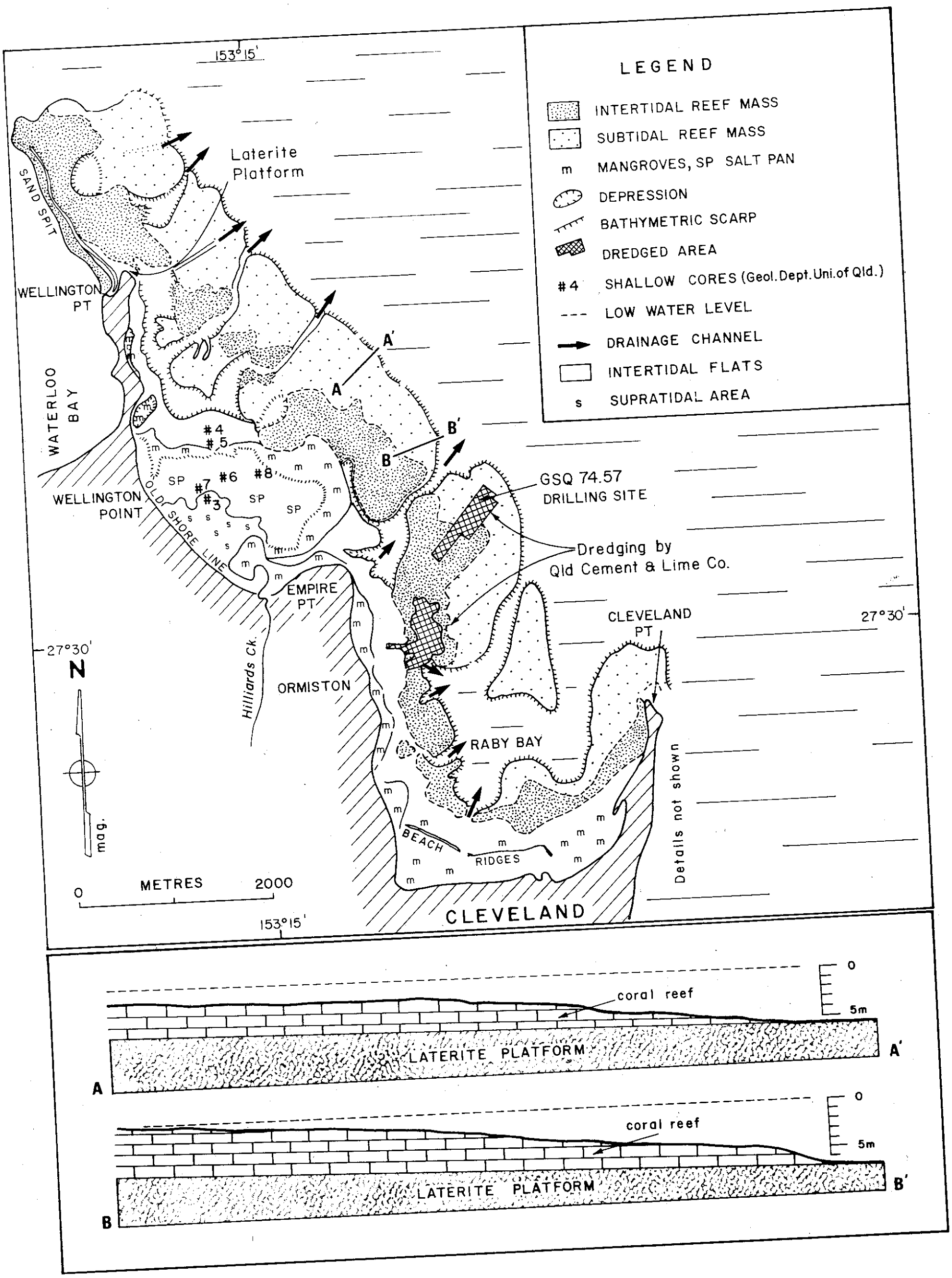
ACKNOWLEDGEMENTS

Mr Dennis Williamson gave technical assistance, and the Department of Geology, University of Queensland provided financial support.

THE FRINGING CORAL REEF

A fringing coral reef has developed between Cleveland Point and Wellington Point. Reef development is almost continuous, except for intervening drainage channels, over a 10 km distance. The reef averages 1 500 m in width (see Text-fig. 1) with the seaward margin approximately 2 000 m off-shore. The framework consists of species of the branching or staghorn coral genus *Acropora*. This once prolific coral growth is now smothered by prograding terrigenous and organic sediment which may be up to 0.5 m thick on the reef surface. Species of Faviidae are the dominant living corals and these are restricted to the subtidal portion of the reef surface. This difference in the composition of the corals represents a marked change in the environmental conditions (*fide* Jones *et al.* this volume) within Moreton Bay. Such a change may be related to increased turbidity of the water produced by progressive siltation of the western waters of the bay by suspended sediment delivered from the Brisbane River during the past 6 000 years, or to the postulated sea-level lowering of approximately 1 m which occurred after 4 000 years B.P. (Jones *et al.* this volume). The latter would have exposed the reefs subaerially and brought about coral mortality. Subsequently less favourable conditions existed for coral growth within Moreton Bay. This is reflected by the decreased diversity of the coral fauna as illustrated by Wells (1955) who was able to distinguish between recent and subfossil coral genera within Moreton Bay.

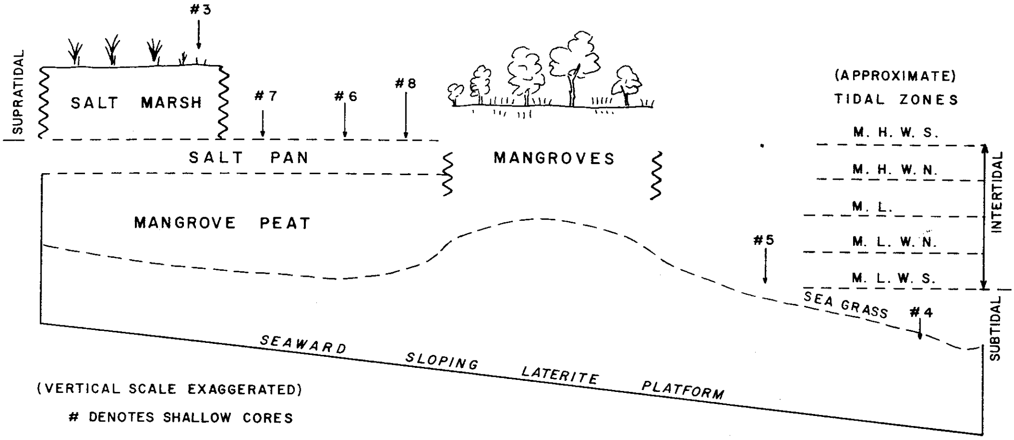
The above mentioned reef began to develop upon a gently seaward-sloping laterite platform (Tertiary in age) similar to that outcropping at Wellington Point, Cleveland Point, and along the intervening coastal stretch. Initial colonization occurred when sea level was approximately 7 m below present mean sea level (i.e. about 7 500 years B.P. – according to the curve of Thom & Chappell 1975). Coral growth did not keep pace with the rising sea level and growth from the deeper parts of the platform has not yet reached the intertidal zone. Only that growth from the platform above -5 m has reached the intertidal zone. If the reef reached the intertidal zone at the same time as the reef at Mud Island where uranium series dates of 4 100 to 6 000 years B.P. have been reported (Jones *et al.* this volume), the rate of vertical reef growth is within the range of 5m/1 000 years to 5m/3 000 years. This rate is in agreement with the value of 3m/1 000 years calculated by Davies & Kinsey (1977) for One Tree Reef at the southern end of the Great Barrier Reef Province.



Text-fig. 1 The distribution of the fringing coral reef and the tidal mud flat between Cleveland Point and Wellington Point. Profiles A A′, B B′ are approximately 500 m in length.

THE TIDAL MUD FLAT

Along the southwestern shore of Moreton Bay the tidal flats which rarely exceed 1 000 m in width display a prominent biotic, hydrodynamic, and sedimentological zonation. This zonation occurs in a contour-like manner on the flat. The width of zonal bands is related to the gradient of the flat. The zonation is similar to that described by Frankel (1976) in his sedimentation model of the Deltaic Deposition System for the Queensland Mainland Coast. The following zones (see Text-fig. 2) may be recognised in



Text-fig. 2 Tidal mud flat zonation and environments (somewhat idealized).

this area: *subtidal zone* – the vertical range extending below mean low water spring tide level (M.L.W.S.); *lower intertidal zone* – the vertical range extending from the lowermost limit of the mangrove vegetation – at approximately mean sealevel (M.L.) down to M.L.W.S.; *middle intertidal zone* – the vertical range incorporates the mangrove vegetation extending from M.L. to the approximately high water neap tide level (M.H.W.N.); *upper intertidal zone* – the vertical range between M.H.W.N. and mean high water spring tide level (M.H.W.S.); *supratidal zone* – the vertical range influenced only by abnormal tides, above M.H.W.S. Distinct sedimentary environments correspond to each of these zones.

Extensive developments of the sea grass *Zostrea nana* may occur at, and slightly above M.L.W.S., and within the subtidal zone (refer to Young & Kirkman (1975) for details relating to the sea-grass communities of Moreton Bay). The sea grasses support a rich epibiota which includes several species of Foraminiferida. They also serve as baffles to trap, and stabilise suspended sediment which has been transported to the area under the influence of either the northeasterly wind waves or the flooding tidal currents, or both. The infauna includes crustacea, polychaetes, and molluscs, all of which cause extreme bioturbation resulting in the homogenous appearance of the sediments. A few centimetres below the exposed surface, sediment is anaerobic due to decaying organic matter. An ubiquitous shell layer (especially abundant is *Anadara* sp.) occurs at a depth of approximately 0.5 m, and at approximately 1 m the sediment abruptly changes from a sandy mud (30% sand/70% mud) to a muddy sand (70% sand/30% mud). The latter is typical of sediment from the lower intertidal zone.

The lower intertidal zone is exposed to wave and tidal-current action. In general, sediment is composed of fine to medium quartz sand with minor amounts of terrigenous and organic mud (80% sand/20% mud). Minor amounts of shelly gravel may also be present. Clean quartz sands occur seaward of beach ridges. A burrowed zone occurs seaward of the lower limits of the mangrove vegetation and its upper surface is commonly covered by the mud whelk *Pyrazus ebeninus*. This zone merges with the *Zostrea nana* vegetation (Plate 1). The surface of the sediment is aerobic. However several centimetres below the surface, it becomes anaerobic because of the decaying organic (mangrove) material present. Numerous burrowing organisms such as worms and molluscs live within this zone and bioturbation is a major factor in homogenisation of the sediment. In some areas the oyster *Ostrea* and mussels have colonized solid substrates within this zone.

The middle intertidal zone is characterised by intense biogenic activity, principally the development of mangroves. The mangrove community is, in this instance, dominated by *Avicennia marina*, but other mangrove types are known to occur within the Moreton Bay region (see MacNae 1966; Lear & Turner 1977). The trees exhibit a variety of growth forms including, saplings and seedlings which extend out over the lower intertidal zone for some distance (Plate 2), pioneer trees exceeding 10 m in height, and the landward fringe of vegetation consisting of stunted growth forms somewhat resembling the spurred mangrove *Ceriops tagal*. Numerous pneumatophores protrude from the lateral roots and these are covered by algae. The diversity and abundance of molluscs, crabs and crustaceans within the mangroves is conspicuous, and the sediment column is being continually reworked; consequently aerobic conditions may extend to a greater depth than in the adjoining zones.

The mangroves produce extremely marked environments of sedimentation. Because they inhibit the movement of waves and tidal currents and associated sediment, they are able to stabilise the surface sediment within the vegetated area. Thus they serve to trap not only the allochthonous clastic sedimentary material but also the autochthonous cumulose deposits of peat derived from the mangrove trees.

The relatively clean sand of the lower intertidal zone is overlain by the fibrous mangrove peat, which is in turn overlain by the laminated sandy mud (30% sand/70% mud) trapped by the algae mats on the salt pan. This may be overlain either by the landward advancing margin of the mangrove vegetation or by the seaward advancing margin of the salt marsh.

The upper intertidal zone coincides with the salt pan environment; a relatively broad flat area which supports extensive developments of algal mats in the more frequently inundated areas, and a salt crust with prism cracks and crinkled algae mats in the less frequently inundated areas (Plate 3). The sediments of the salt pan are usually 0.3 m thick consisting of brownish sandy mud (20% sand/80% mud). The surface sediments overlie mangrove peats and black muddy sediments, which in turn overlie grey sands similar to those of the lower intertidal zone. A slight height increase and the extensive occurrence of halophytes marks the junction between this zone and the mangrove vegetation, whereas the junction with the supratidal salt marsh environment is marked by a salting cliff about 0.3 m high. Oxidation of sulphide minerals within the sediments contrasts with the reducing conditions prevailing elsewhere. This oxidation produces a colour change towards red and yellow, which tends to accentuate the mottling of the sediment.

The supratidal zone includes the salt marsh environment whose substrate may be influenced by the highest of the spring tides but which is rarely inundated by salt water. The sediments of the salt marsh are predominantly muddy with a major contribution of organic material derived from the marsh grasses. The thickness of sediment rarely exceeds 1 m. The beach ridges which occur in Raby Bay are included within the supratidal zone. These ridges are composed of medium to coarse sand-sized quartz and carbonate material similar to the sediment of the lower intertidal zone. In plan, they are straight, up to 1 000 m long, rarely over 2 m high and support a dry scrub vegetation which may include *Casuarina.* The ridges are formed by the action of breaking waves on the gently shoaling intertidal surface. Subsequent to their formation they may be colonised on both their seaward and landward sides by the pioneer mangrove *Avicennia.*

THE HISTORY OF HOLOCENE SEDIMENTATION

The history of Holocene sedimentation along the southwestern shores of Moreton Bay is divisible into two distinct phases: a transgressive period from about 7 500 years B.P. to between 6 000 – 4 000 years B.P., and a regressive phase since approximately 4 000 B.P. to present.

Transgressive phase

During the post-Pleistocene (Flandrian) transgressive phase of sea level rise, corals colonised a pre-existing seaward-sloping laterite platform. Growth started at 6 m below present L.W.D. approximately 7 500 years B.P. Reef development was unable to keep pace with the rising sea level and only that coral growing from depths less than –5 m has reached the present intertidal zone. This might have occurred between 4 000 to 6 000 years B.P. As the sea transgressed across the laterite platform it reworked to shoreward clastic quartz sediments similar to those occurring within the present lower intertidal zone. During this time the oceanic water entering Moreton Bay was able to support a rich coral fauna (subfossil coral fauna of

Wells 1955) consisting of *Acropora* spp. which built the framework of the coral reefs.

Regressive phase

The regressive phase may consist of two distinct parts; a relatively rapid drop of sea level of the order of 1 m sometime between 4 000 to 3 000 years B.P. (see Fairbridge 1976), followed by relative increase in the elevation of "base-level" produced by land-building processes operative within the tidal zone (see Davis 1940). The latter is indicated in shallow cores collected throughout the tidal flat. These display a systematic pattern of lithofacies. Vertically the sediments exhibit an upward progression of higher tidal-zone lithofacies, as well as lateral sequential development of lithofacies (see Table 1). The lateral migration is evident in that the upper surface of the coral reef is presently colonised in places by mangrove vegetation (Plate 4). Also within Raby Bay the distribution pattern of mangroves has altered markedly during the past 30 years (Plate 5) whereas in the area northwest of Empire Point very little change has occurred (Plate 6).

TABLE 1

SUMMARY OF DETAILS PROVIDED BY THE SHALLOW CORES

CORE	ENVIRONMENT	THICKNESS'	% SAND	% MUD
3	SALT MARSH SALT PAN	0.3 0.2+	10 10	90 90
7	SALT PAN MANGROVE (PEAT)	0.3 0.2+	44 87	56 13
6	SALT PAN MANGROVE (PEAT) LOWER INTERTIDAL FLAT	0.3 0.3 0.5+	27 - 85	73 - 15
8	SALT PAN MANGROVE (PEAT) LOWER INTERTIDAL FLAT	0.3 1.2 1.0	5 80 85	95 20 15
5	LOWER INTERTIDAL FLAT (*Pyrazus* zone)	1.0+	85	15
4	SUBTIDAL FLAT (*Zostrea* zone) LOWER INTERTIDAL FLAT	0.8 0.2+	30 70	70 30

'Thickness in m.

Present day sedimentation occurs mainly during the summer months when the prevailing winds are from the northeast coinciding with the high rate of discharge of suspended sediment from the Brisbane River. Sediment is transported southwesterly and a portion of it is deposited on the tidal flats.

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PLATE EXPLANATION

Plate 1 **The lower intertidal zone**

Fig. 1 *Zostrea nana* acts as baffles trapping and binding suspended sediment.

Fig. 2 *Pyrazus ebeninus*, the mud whelk, browses over the muddy sands of lower intertidal zone.

PLATE 1

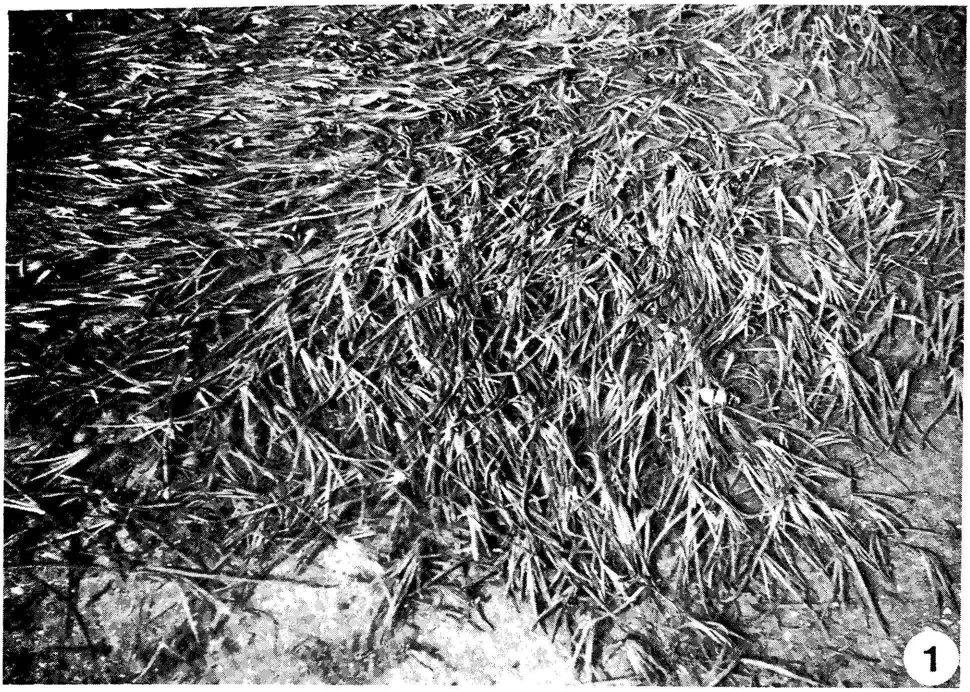


PLATE EXPLANATION

Plate 2 **The middle intertidal zone**

Fig. 1 Showing the seaward fringe of the mangrove (*Avicennia*) vegetation. Saplings, seedling, and the pneumatophores from the lateral roots trap fine-grained sediment.

Fig. 2 Within the *Avicennia* growth, the surface is totally covered by pneumatophores.

PLATE 2

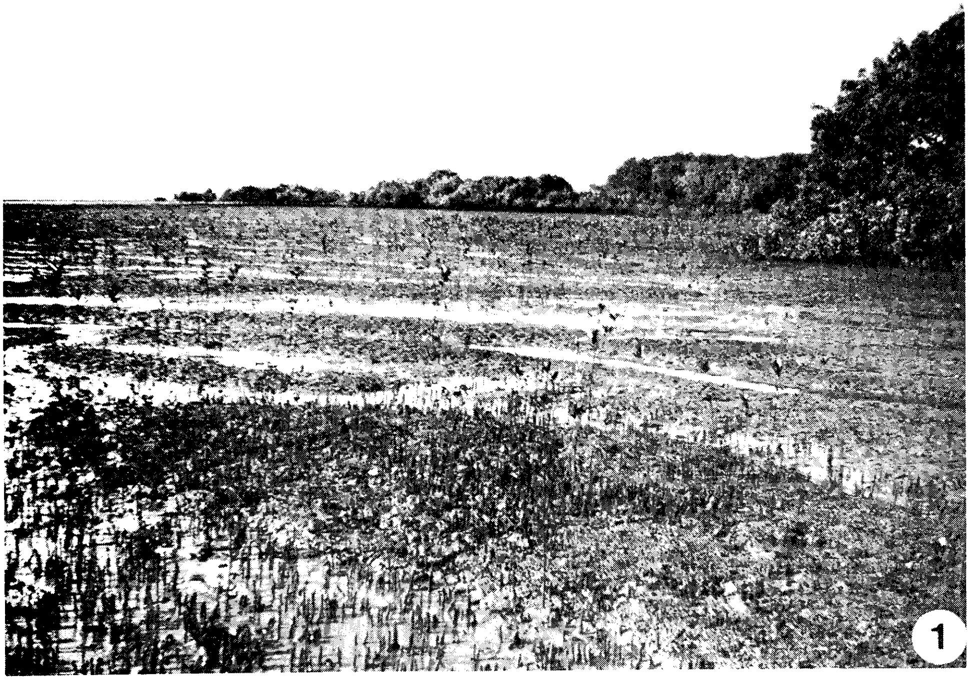


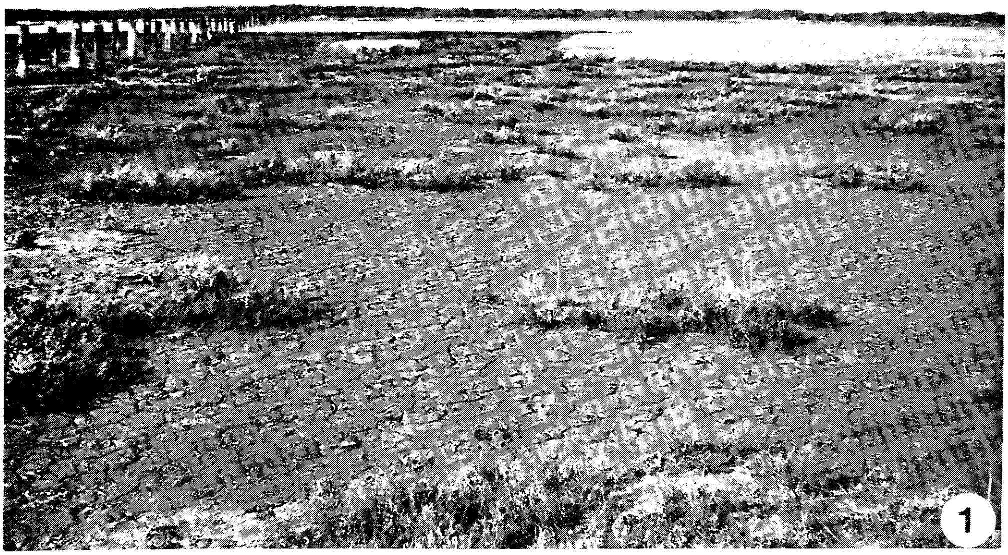
PLATE EXPLANATION

Plate 3 **The upper intertidal zone**

Fig. 1 Surface of the salt pan adjacent to the salt marsh (the light-coloured grassed area). Halophytes tend to colonise any slightly elevated area producing irregularly spaced clumps. The junction between the salt pan and the salt marsh is marked by a 10 to 30 cm cliff.

Fig. 2 Surface of the salt pan showing the crinkled algal mats, prism cracks underlying the recently formed mats, and a clump of halophytes.

PLATE 3



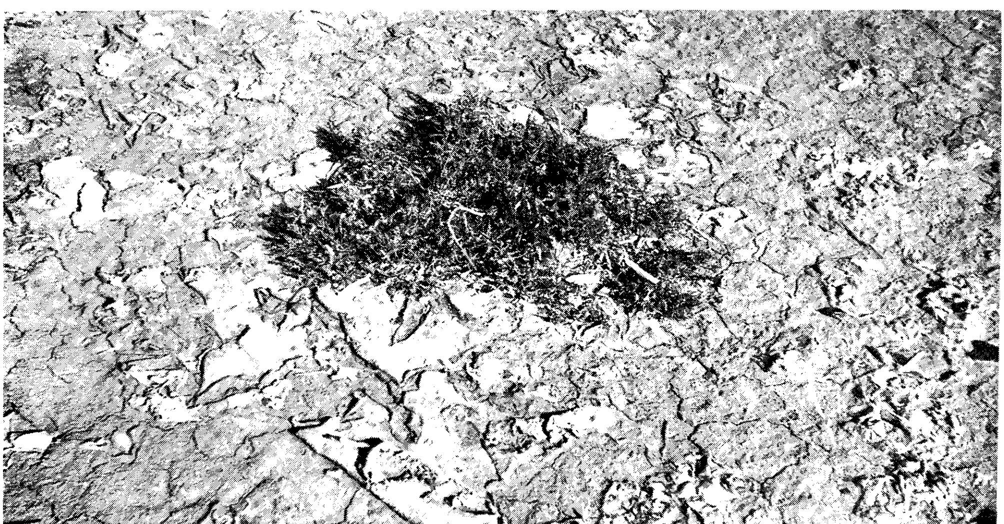


PLATE EXPLANATION

Plate 4

Portion of an aerial photograph (1972) showing the prograding nature of the mangrove vegetation (4) extending across the intertidal portion of the reef mass (between 4 and 1). The seaward submarine scarp of the coral reef is evident near (1). The reef is being dredged at (2) and (3).

PLATE 4

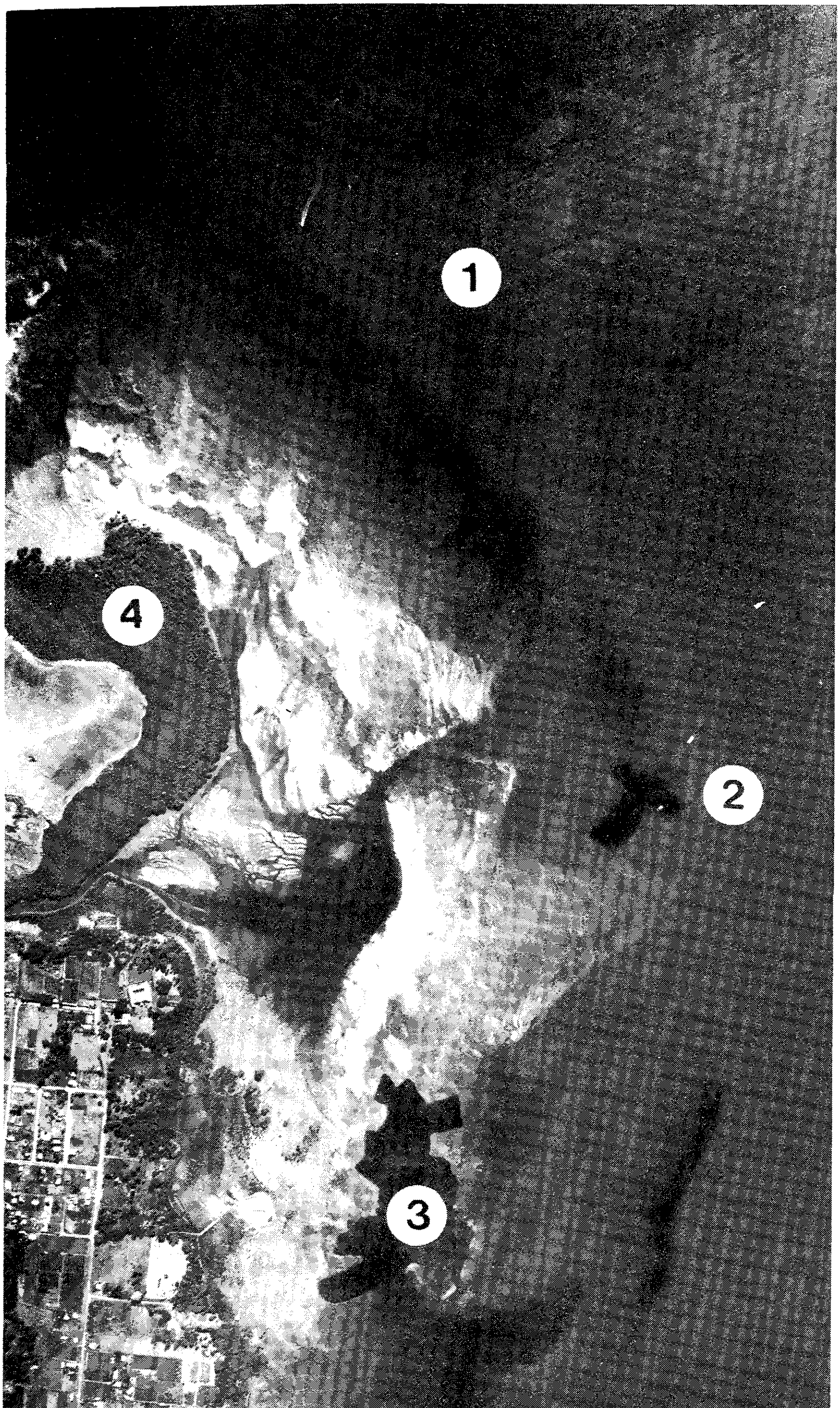


PLATE EXPLANATION

Plate 5

Portions of aerial photographs taken in 1944 (1) and 1972 (2) showing the colonization of the tidal mud flat of Raby Bay by mangroves (*Avicennia*) within that thirty year period.

PLATE 5

PLATE EXPLANATION

Plate 6

Portions of aerial photographs taken in 1944 (2) and 1972 (1) showing the obvious zonation of the tidal flat. This area adjoins that shown in Plate 4. The mangrove vegetation has altered very little during the thirty year period.

PLATE 6