THE STRUCTURE AND DEVELOPMENT OF FRINGING REEFS OFF THE GREAT BARRIER REEF PROVINCE

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Introduction

Within the Great Barrier Reef Marine Park area there are some 618 high continental islands and a mainland coastline of several thousand kilometres. Fringing reefs are common on many of the islands and are found on the mainland, particularly to the north of Cairns. Some 545 fully developed fringing reefs have been identified with a further 213 incipient fringing, reefs within the Park area. However, the.fringing reefs extend further south than the southern limits of the Marine Park and are found on the Queensland coast within Moreton Bay and extending south to the Solitary' Islands off the New South Wales coast. Further offshore the southernmost reefs in the world are found as fringes around Lord Howe Island at 31°35' south. Within'the Park the fringing reefs have a total area of about 350 km^2; small compared to the total reefal area of the oute'r reefs which are approximately 20,000 km^2.

In spite of the relatively small area, the fringing reefs are however important for a number of reasons.

1) All but three of the Great Barrier Reef resorts are located on high continental islands and fringing reefs are therefore the most easily accessible and the most commonly seen by the majority of visitors to the Great Barrier Reef.

2) The fringing reefs are closest to the mainland and therefore are most susceptible to anthropogenic influences resulting from land use changes and industrial development.

3) Although fringing reefs are limited to the inner shelf zone now, they were probably the most common reef form throughout the period of development of the Great Barrier Reef of the Quaternary period during the last 2,000,000 years. During this time low sea level phase dominated and at best, reef development occurred as fringes around older reef limestone foundations formed during the short inter-glacial periods of high sea level. At the lowest sea level stage, as for example 18,000 years ago, fringing reefs on the steep shoulder of the Continential Shelf were the only reef form occurring in Queensland. Fringing reefs therefore have an important historical part in the total development of the Great Barrier Reef. (Hopley, 1982, Ch. 6, 12)

A Structural Classification of Fringing Reefs

Over the last 13 years since the 1973 Royal Society Expedition an enormous amount of data has become available on the structure of reefs of the Great Barrier Reef through shallow drilling programmes, particularly those carried out by the Bureau of Mineral Resources (Dr. P.J. Davies), and James Cook University (A/Professor D. Hopley). Fringing reefs make up a small proportion of the data set (table 1). However, structural information, from radio-carbon dated cores is available for eight separate fringing reefs: Hayman Island (Hopley et al., 1978); Pioneer Bay, Orpheus Island (Hopley et al., 1983); Iris Point, Orpheus

Island (Hopley & Barnes, 1985); Fantome Island (Johnson and Risk, in press); Rattlesnake Island (Hopley et al., 1983); and three reefs of the Cape Tribulation area (Partain, this conference). In addition further information is available for several of the resort islands where jet probes or drilling has been carried out for jetty construction, etc.

The sea level scenario in which reef growth has taken place has been one of a rapid rise (circa. 7 mm per year) up to approximately 6,500 years ago when modern sea level was first achieved. Subsequently because of the inner shelf situation of the fringing reefs'a location in which some hydroisostatic uplift.can potentially take place, there has been a relatively higher sea level of up to +1.5 m involved in the development of the fringing reefs. This higher level was reached approximately 5,200 years ago and sea level has slowly subsided in a relative sense to its present position. Because of the relatively shallow nature of the, inner shelf within which most of the fringing reefs are situated, drowning of even the lowest portions of the sea floor around the high islands (circa. -20 m) took place only some 8,000 years ago. For mainland fringing reefs where the water depths are even less submergence probably took place little more than 7,000 years ago. However, as, noted, previously by Davies et al. (1985) there may have been'a significant delay in the recolonisation of the reef foundations of the outer, reefs during the Holocene transgression which has meant that foundation dates for, the Holocene reef even for the outer reefs, are little more than 8,000 years B.P. Thus the fringing reefs of some of the outer continental islands may have been initiated at approximately the same time as their outer reef counterparts.

* The following is a suggested classification (fig. 1):

1) Simple reefs formed from the foundation on the lowest portion of the rocky foreshore during the Transgression These reefs were developed while the sea level was still rising. Most of their development has gone into upward growth over the rocky slopes of the island, following the Transgression. After the still-stand period and when the reef had reached sea level a small amount of outward growth may have been possible over the reef's own forereef talus slope. On the whole such reefs are growing from relatively deep water and reef flat development is therefore limited due to the great vertical extent of these reefs. Their structure is thus one of a basal framework unit immediatley over rock and then a small biogenic detrital frontal unit with thin reef flat veneer. Examples include the narrow fringing reefs on the windward side of the Palm and Whitsunday Islands, and probably the more narrow reefs on steep rocky shores of the Cape Tribulation area.

* 2) Reefs developed over more gently sloping substrate, particularly where older foundations of Pleistocene reefs may be present In these instances the reef foundation is initiated offshore from the present coastline, although would probably have started as a fringing reef as sea level would have been lower at the time. The rising sea level however, isolated this initial reef which continued to grow upwards during the transgressive phase as an offshore barrier. Possibly because of poor circulation and terrigenous input growth behind this barrier was very slow. After the still-stand and after

the reef had reached sea level, the outer reef became attached to 'the island by lagoonal infilling, this infill coming from both the land as a terrigenous unit and from the outer reef as a biogenic carbonate unit. Following the still-stand, some small outward growth may also have taken place. The structure is therefore one of a. framework unit offshore from the present shoreline and an interdigitated terrigenous and biogenic detrital fill behind the framework. A thin, reef flat framework veneer may be present over the entire reef and a small, reef front biogenic talus may also 'be present. The best example of this type of reef is provided by Hayman Island, developed over. an older Pleistocene reef. (fig. 2)

* 3) <u>Reefs developed over pre-existing positive sedimentary structures</u>

Reefs have long been regarded as requiring hard substrate for initiation. However, there is increasing evidence from North Queensland reefs that the presence of even a muddy sedimentary' structure with positive relief may greatly enhance or speed up reef flat development. Such sedimentary structures may be in the form of terrigenous mud/sand banks or barriers, lee side sand spits attached to islands, boulder beaches, deltaic bar gravels, and low angle Pleistocene alluvial fans. During the transgressive phase, even though' a bank may have existed previously no reef development is possible because of the inhospitable nature of the substrate. However, once the rocky shores of the adjacent island or' mainland are inundated reef colonisation takes place rapidly on these shores at shallow depth. Progradation 'of the reef is then rapid over the pre-existing structure with hard substrate now being provided over

the sedimentary base by the forereef talus from the prograding reef front. The structure of such reefs is thus one of a basal terrigenous sedimentary unit, an' inner framework with a prograding carbonate detrital unit extending over the terrigenous base, and an upper, thin, generally less than 4 m, reef flat framework veneer. Examples show the range of the existing sedimentary structures, and include:

a) Pioneer Bay (fig. 3) and Fantome Island where terrigenous sand/ mud wedges provide the sedimentary foundation and were probably brought inshore by wave action during the Transgression.

b) Rattlesnake Island (and probably numerous other small islands with large, lee side fringing reefs) where the foundation is provided by lee side sand spits similar to the more recent spits developed over the top of the reefs themselves (fig. 4).

c) Great Palm (fig. 5) and Magnetic Island (fig. 6) reefs where the carbonate reef appears to be extremely thin, and developed over low angle Pleistocene alluvial fans.

d) Iris Point, Orpheus Island where the rocky shore of the island is bordered by a well sorted Pleistocene boulder beach which extends beneath the Holocene reef flat and appears to have provided the foundation of the reef flat (fig. 7).

e) The cuspate reefs of 'the Cape Tribulation area where the foundations are provided by deltaic fan gravels. Modern streams often debouching over reef flats show similar deltaic gravel fans. Changing'location of a creek mouth with migration has led to a very widespread gravel fan formation along this coast, and hence the continuity of fringing reef development. Apparent spur and groove systems on these reefs may reflect the gravel bar structures'rather than the normal high energy control which produces windward spur and groove formations (see Partain, this conference).

Comparative Growth Rates of Fringing Reefs

In a review of Holocene reef growth in the Great Barrier Reef province, Davies and Hopley (1983) indicated that fringing reefs grew at rates comparable to middle and outer shelf reefs, though usually at the' lower end of the growth scale, i.e. for framework construction in the range of l-4 mm per year. This may be in part a reflection of the greater proportion of massive as opposed to branching, framework. As with outer reefs the fringing reefs showed a bimodal detrital accretion rate, a lower range of l-5 mm per year representing accumulation under, normal weather conditions, but with higher rates up to 15 mm per year indicative of infrequent high energy cyclonic events. Data from all the drilling results of both the BMR and JCU programmes has also been plotted as growth rate against depth of water at the time of growth (fig. 8). Data used here includes results subsequent to the earlier 1983 paper. Fringing reefs show genera'lly, very low growth rates in shallow water, particularly

when compared to the mid-shelf reefs which have both a protected situation and clear water. The lower rate for fringing reefs is probably a reflection of the turbid water conditions and periodic decline in salinities. However, at depths between 4 and 7 m, fringing reef growth seems to be at least equal to the rate of growth of both . mid-and outer-shelf reefs. Below this depth there appears to be a rapid decline in accretion rate. This is interpreted as the result of the high turbidity of inshore waters and rapid decline in light levels at these depths. Equivalent decline in growth rates for outer reefs takes place below approximately 15 m.

Surface Features of the Fringing Reefs

Fringing reefs, particularly the larger lee side reefs show a remarkably diverse range of morphological features. Windward fringing reefs have a zonation which is similar to that of mid-shelf reefs with a well defined energy gradient evident across the reef. Features such as algal pavement, shingle ramparts, and wide turf algal zones typify many reefs in these situations. The largest fringing reefs are frequently found on the lee side of smaller islands with minimal run-off (see Hopley, 1971). These have a remarkably similar range of features to the low wooded islands which are found on the inner shelf to the north of Cairns (see Philosophical Transactions, Royal Society London, 1978; Report of 1973 Royal Society Expedition for detail). This similarity is not surprising. Fringing reefs and low wooded islands have a similar inshore location, rising from similar water depths with similar exposure to sediment laden fresh water plumes. They also have a very similar sea level history because of their

inner shelf location with a small amount of hydroisostatic emprgence'of approximately l-l.5 m, approximately 5,000 years ago. The cays of the low wooded islands are reciprocated by the sandy spits extending across the lee sides of fringing reefs, both have a series of terraces with graded soil profile development across them with similar age sequences, back to approximately 6,000 years. The platform rocks of the low wooded island have their equivalent in the beach rock terraces, both extending over emerged micro-atoll fields. Basset edges formed by'the cementation of shingle ramparts are also found in both environments. Mangroves with associated peats up to 1 m in thickness can also be found on both low wooded islands and lee side fringing reefs. Shingle ramparts are common and the moated pools which they enclose contain large micro-atoll pools. Variations in the rampart systems due to cyclonic interference has been reported from both low wooded islands (e.g. Moorhouse, 1936) and high island fringing reefs (e.g. Hopley & Isdale, 1977).

Questions and Problems relating to Great Barrier Reef Fringing Reefs

This Workshop is deservedly giving fringing reefs the prominence which they have formerly lacked. A review of the geomorphological research already carried out on these reefs suggest that there are a number of prominent'questions which need to be addressed in the near future.. These include:"

(a) With the exception of the foundations of Hayman Island reef and also Cockermouth Island reef formed from dune calcarenite there are no reports of Pleistocene last inter-glacial reefs from either the mainland or high islands. Pleistocene foundations of the modern reefs are almost without exception non-carbonate. This is in spite of the fact that the last inter-glacial high still-stand a few metres above present sea level is well documented for mainland locations. The question arises as to whether or not it was possible for near shore reefs to'develop during the last inter-glacial and if not, why not? Alternatively it is possible that severe erosion has taken place which has removed all visible vestiges of these earlier reefs. This is not the case however, elsewhere in the world, and it is most probable that there was a very poor development of such reefs 125,000 years ago. This question requires further research.

(b) Fringing reefs clearly can be highly productive in terms of laying down a carbonate framework, even in areas apparently non-conducive to reef growth. Why should this be so? Is it possible that there are specialised communities which will survive in the more fluctuating environment of the near shore zone as compared to the outer reef? Further ecological work on near shore communities is obviously required.

(c) For the mid- and outer-shelf reefs the major geographic variation in growth rate and framework construction appears to be longitudinal across the shelf rather than latitudinal. However near shore waters

have much greater latitudinal environmental variations than do the mid- and outer-shelf waters, and to date. information on fringing reefs is limited to the Central Section of the Great Barr'ier Reef. Further work is needed on both reefs at the southern end of the Great Barrier Reef Marine Park and extending as far north as Torres Strait. This may indicate some significant south to north gradients for these near shore reefs.

(d) The southern limits of significant fringing reef development off the Queensland coast provide a fascinating research question. At about the latitude of Mackay in the Cumberland group of islands, there is a very sharp line of demarcation between wide, well developed fringing reefs to the north and poorly developed (at best, incipient) fringing reefs to 'the south. The reasons for this are being investigated and may include effects of the greater energy related to high tidal,range, the effects of open ocean swells and Tasman Sea waters entering into the Great Barrier Reef region via The Capricorn Channel, or alternatively the effects of the flow from the Fitzroy River, Australia's second largest river system. An understanding of the distribution of reefs in this area is seen as particularly significant as the region has the greatest concentration of tourist development of any part of the Great Barrier Reef.

(e) Further work is requir'ed on the viability of near shore fringing reefs. 'Because they are so close to the mainland they will be the first to feel the' effects of any pollution or man-made perturbation and therefore, in many respects may be seen as the initial monitors

for the whole of the Great Barrier Reef province. Degradation of some fringing reefs (e.g. in the Bowen area) has been documented for over 50 years. However, many of the comments made are based on qualitative, subjective information and it would seem appropriate at this time that a more scientific approach be adopted towards the monitoring and detailing of the immediate past history of the fringing reefs.

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Table 1

DATA BANK FOR NORTH QUEENSLAND FRINGING REEFS

Reef	No. Holes	Max. Depth (m)	No. C^{14} Dates (incl. reef flat)	Oldest Holocene C^{14} Date	Oldest C^{14} Date within 1 m of Reef Flat Level
Iris Pt., Orpheus Is.	7	8	12	7320 ± 125	6260 ± 120
Pioneer Bay, Orpheus Is.	3	17.25	10	6610 ± 250	5970 ± 100
Fantome Island	3	10	17	5520 ± 100	5520 ± 100
Rattlesnake Island	1	10	5	7010 ± 180	5530 ± 130
Hayman Island	6	47	15	9320 ± 730* (8300 ± 500)	4090 ± 150
Cape Tribulation Reefs					
. Rykers Reef	4	6.95	8	n.a.	n.a.
. S. Myall Reef	3	8.3	4	n.a.	n.a.
. Emmagen Reef	2	5.8	3	n.a.	n.a.

* Questionable Date

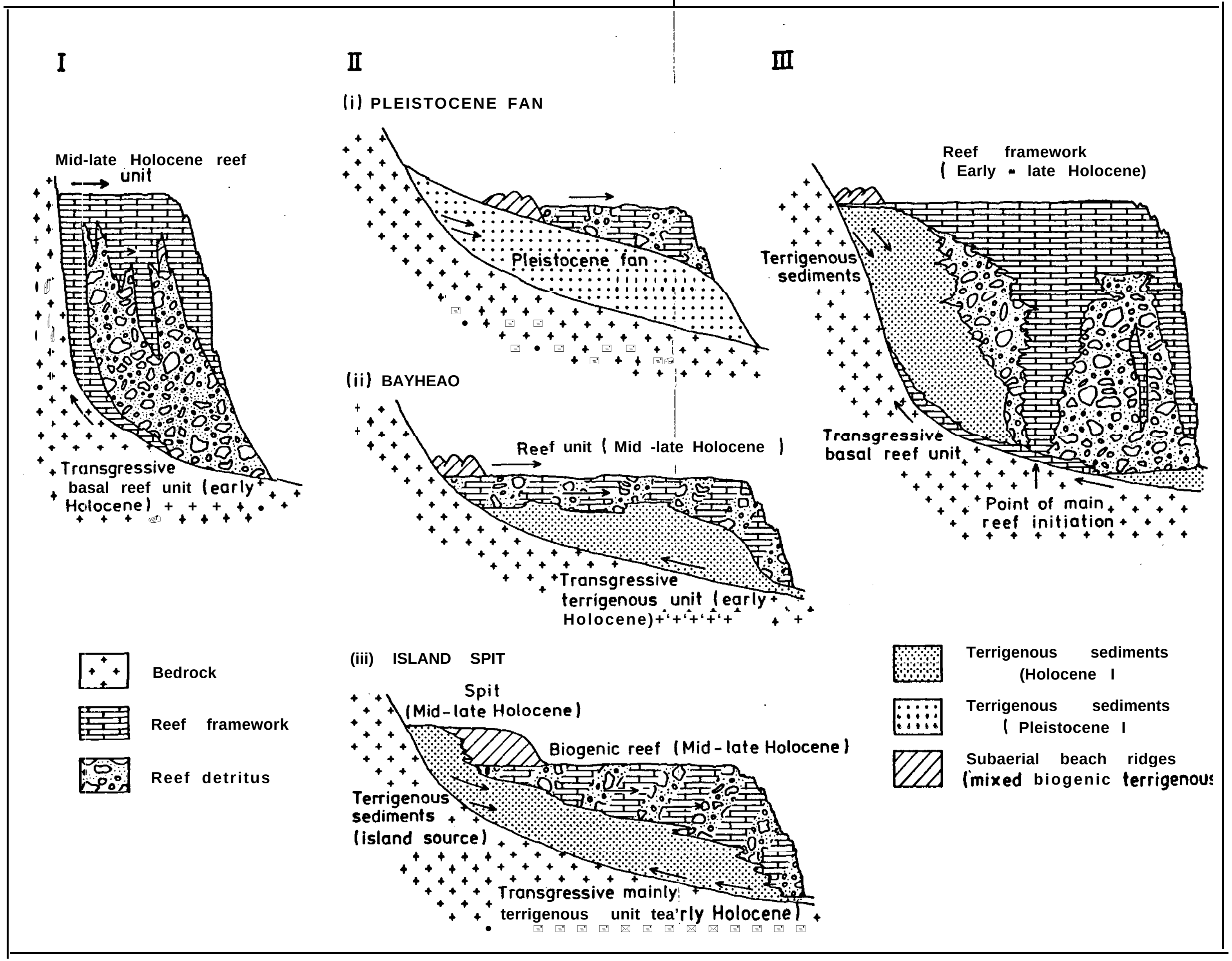

Figure 1: A Structural Classification of Fringing Reefs

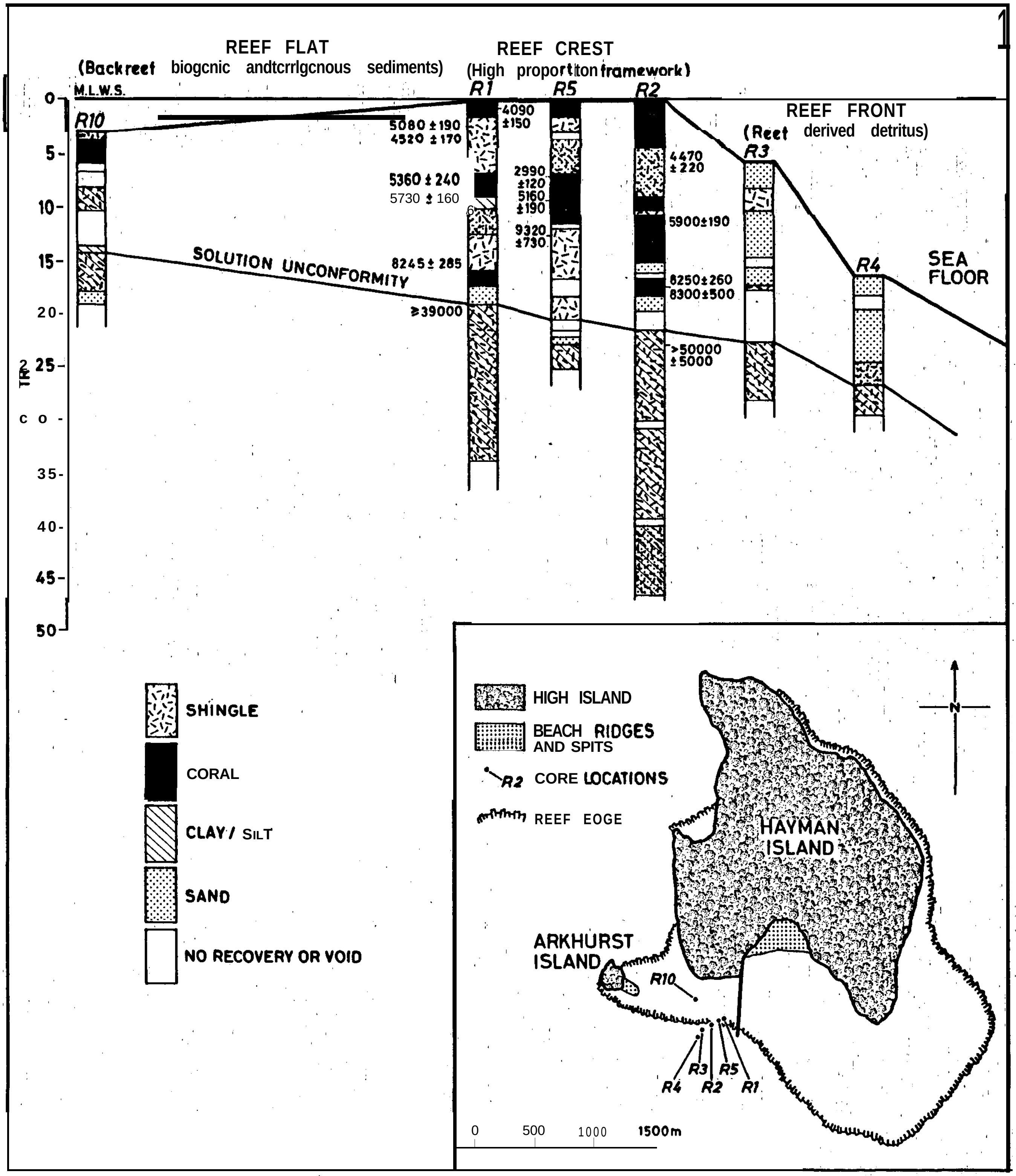

Figure 2: Hayman Island Fringing Reef

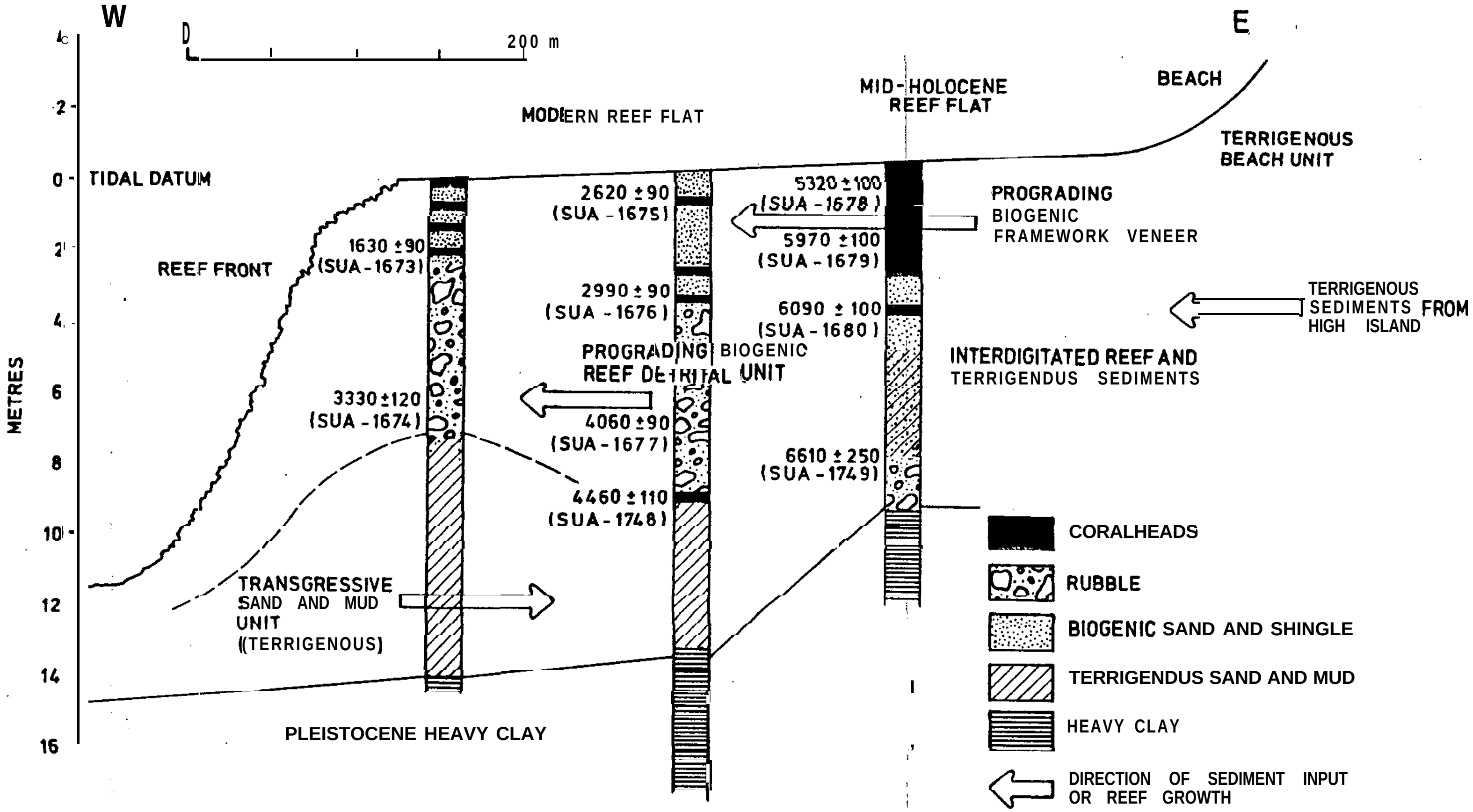

Figure 3: Pioneer Bay Orpheus Island Fringing R&f, Section and Dated Drillholes

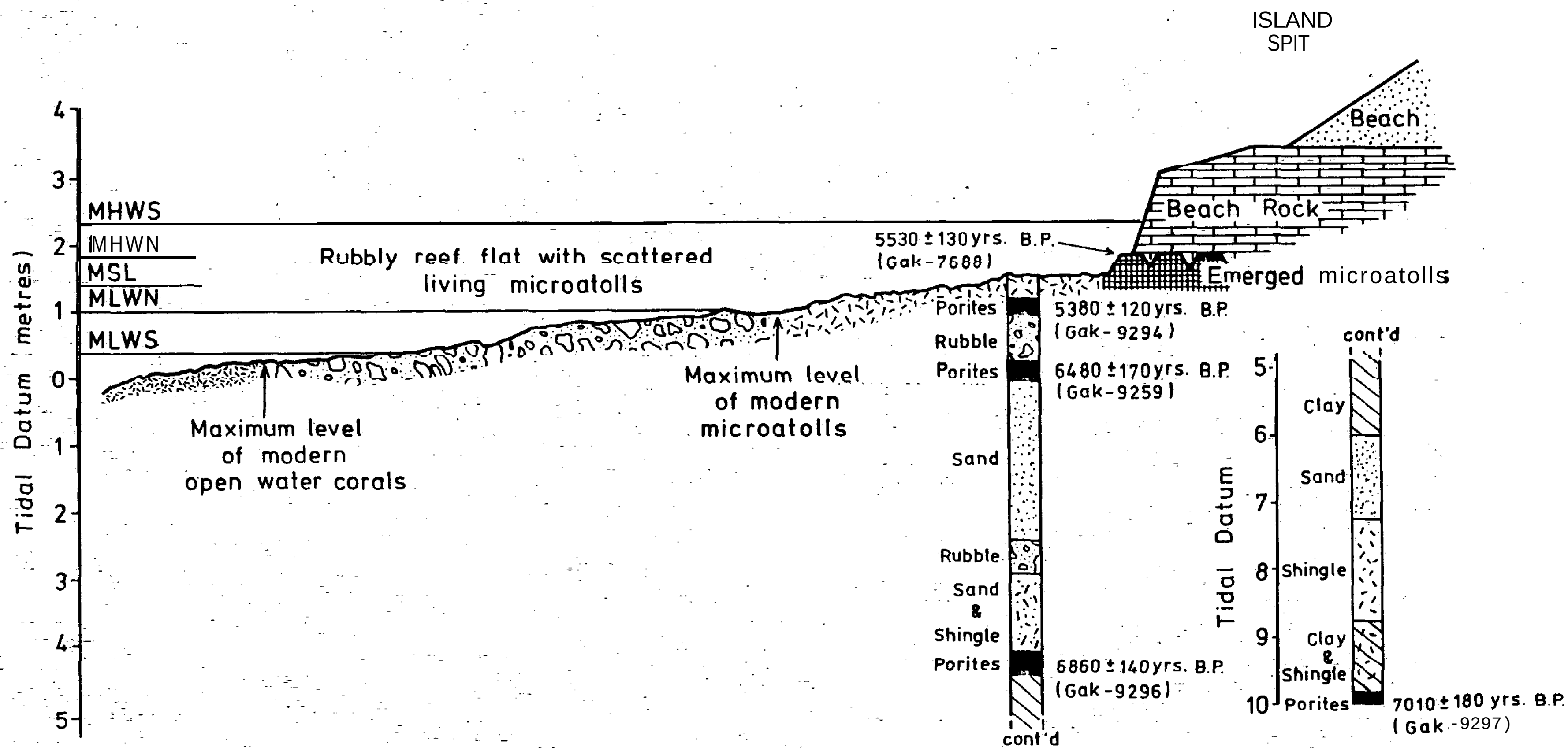

Figure 4: Results of drilling Rattlesnake Island Fringing Reef

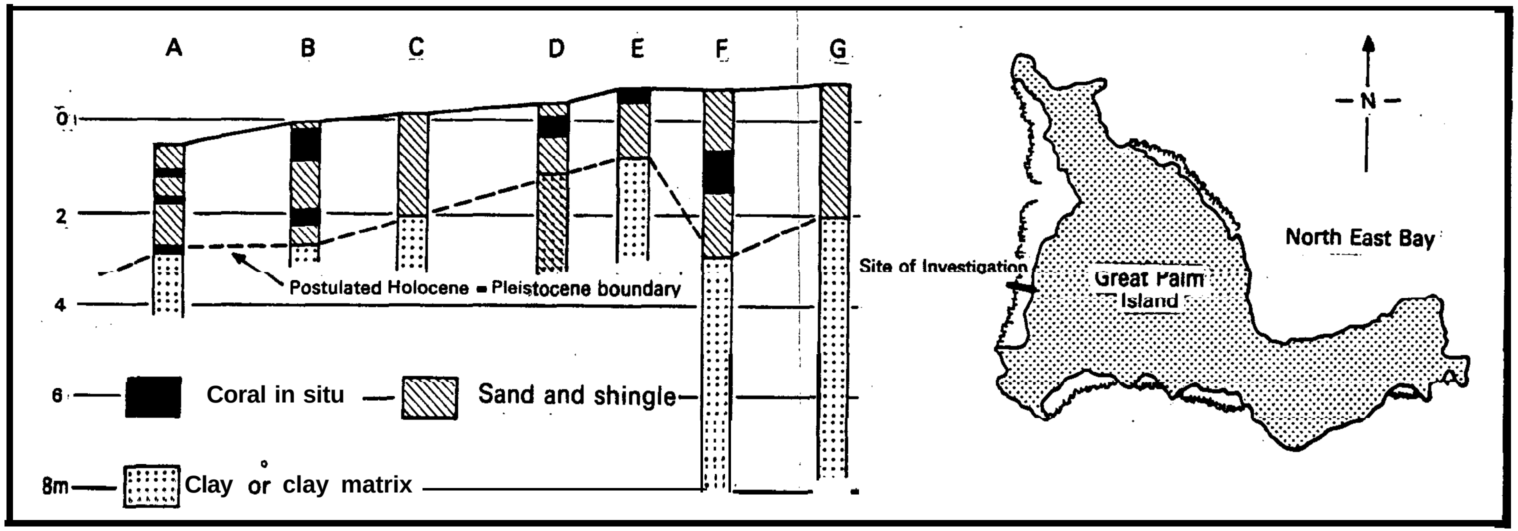

Figure 5: Structure of Fringing Reef by Aboriginal Settlement Great Palm Island based on engineering jet probes.

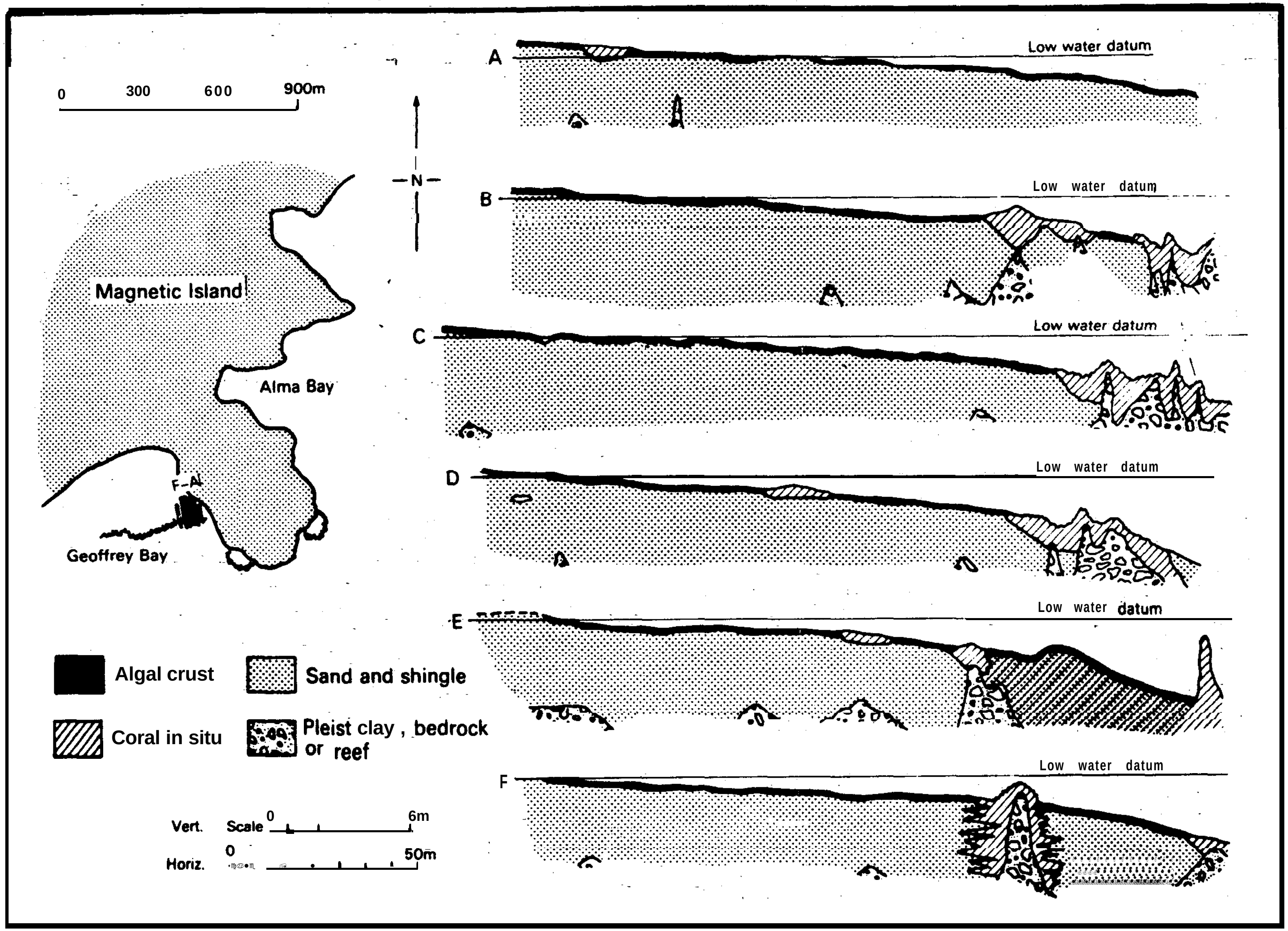

Figure 6: Geoffrey Bay Magnetic Bay Fringing Reef Structure from jet probes

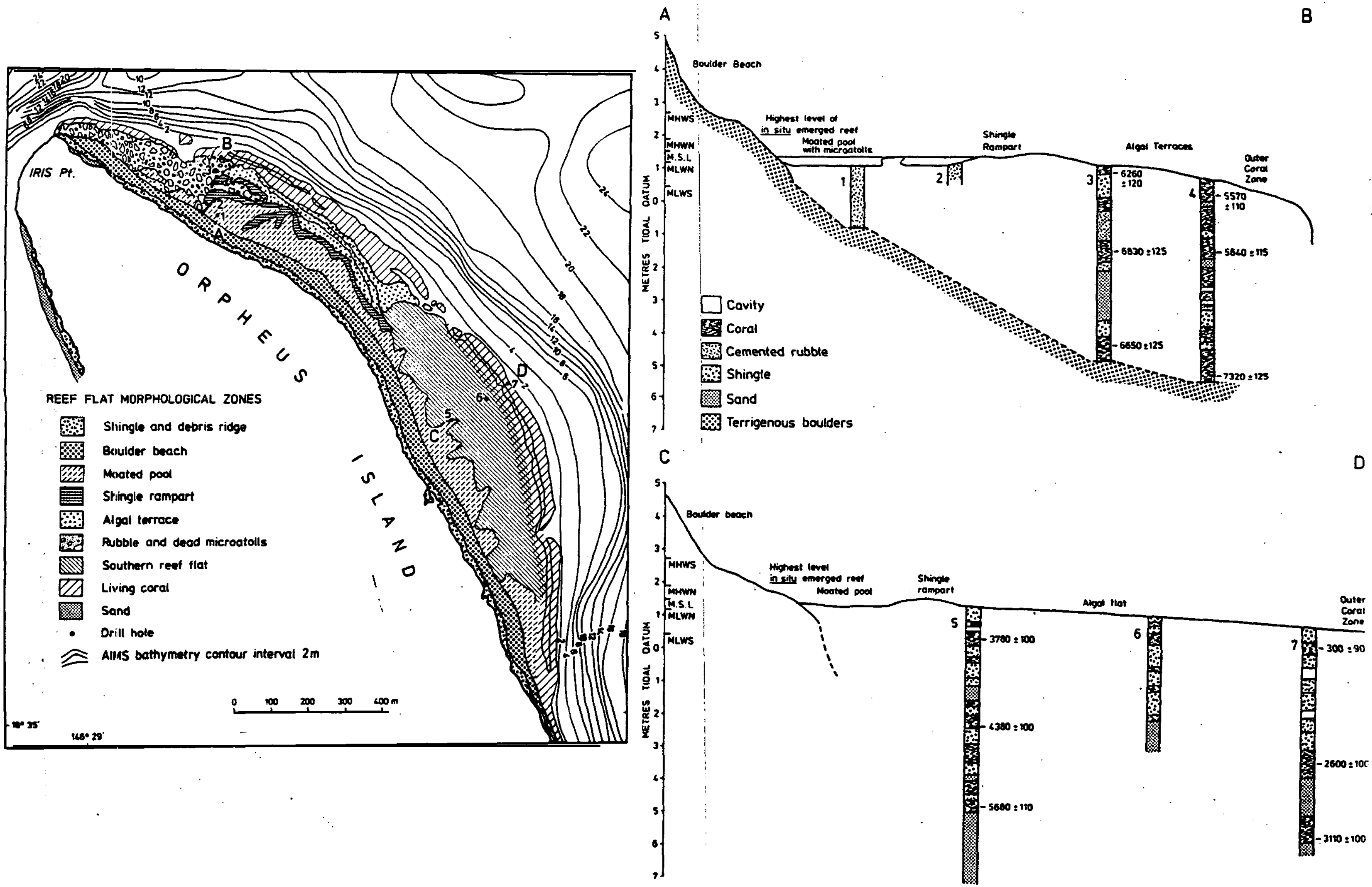

Figure 7: Iris Point Orpheus Island Fringing Reef Structure

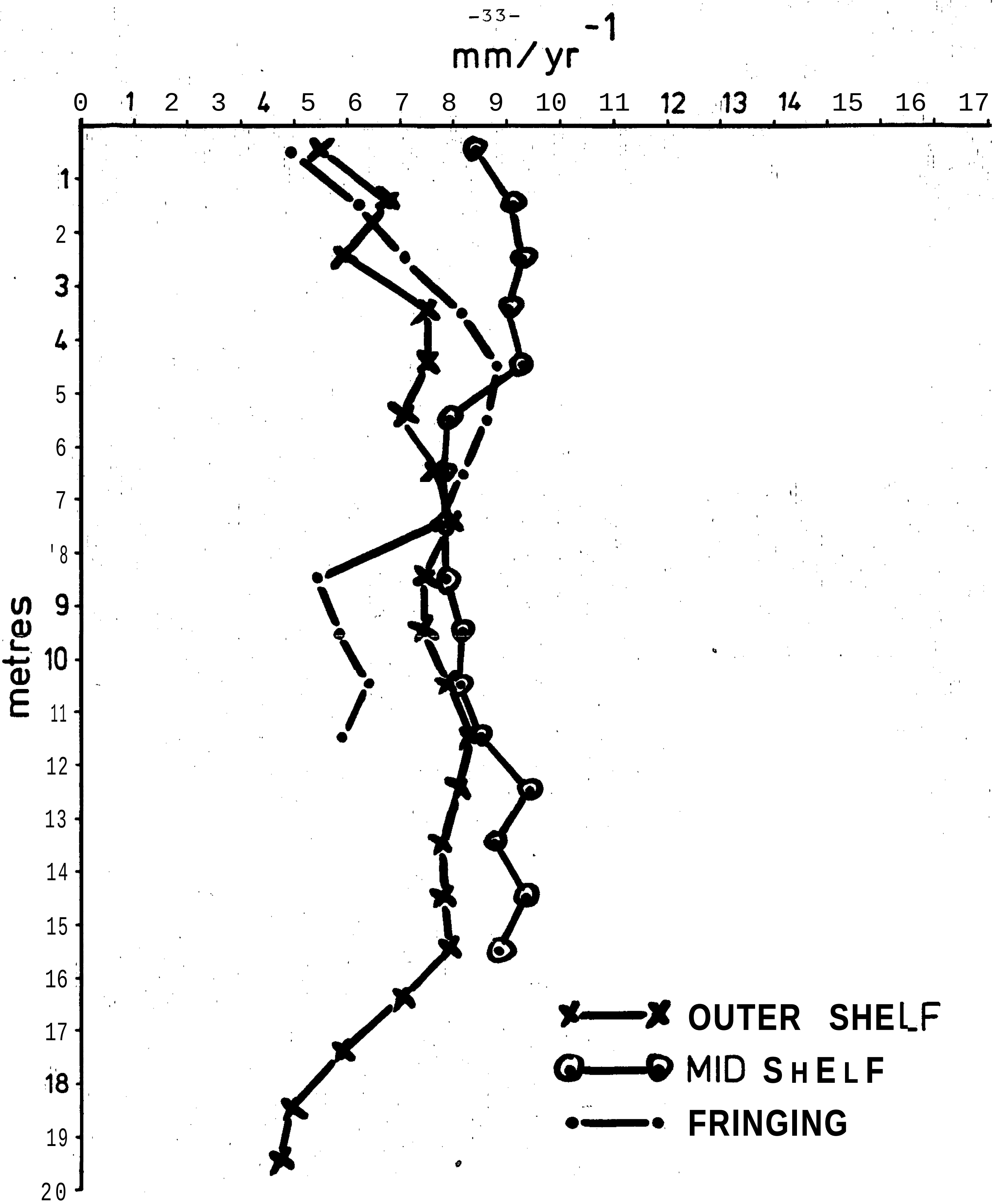

Figure a: Growth Rate versus depth of water for Fringing mid-shelf and outer-shelf reefs, Great Barrier Reef.