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THE STRUCTURE, FORMATION AND SPECIES DIVERSITY OF SOUTH INDIAN REEFS

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ABSTRACT

A well developed reef, the 'Mannar Barrier' stretches along the southeast coast of India, from Rameswaram Island to Tuticorin in a northeast, southwest direction, to a distance of nearly 140 km. This formation is bridged by a shallow ridge, 'Adam's Bridge' to the reefs of Ceylon. On the leeward side of the reef flat, there are 20 small islands which are more or less 5 sq. km in size and mostly of the same elevation as the mainland coast. Since sediment supply was considered inadequate on the flat for the formation of these islands, it is suggested that they are parts of the mainland, which got separated by a wide subsidence in Sub-Recent time during which Ceylon also finally severed its connection from the mainland of India. This subsidence caused a wide lagoon-like portion of the sea resulting in the 'Mannar Barrier'. The fringing or patch-reefs found on the leeward side of the sand cays, as well as in the Palk Bay are Secondary Formation on shallow waters where granite or laterite substratum was exposed by erosion.

While the southern part of the barrier has very few species dominated by Pocillopora damicornis, Acropora spp., Montipora spp. and Turbinaria spp., the northern portion has a rich diversity of genera and species dominated by Poritids and Faviids, along with Pocilloporidae and Acroporidae. The encrusting calcareous algae are very significant as a reef builder at the south, while insignificant down north.

KEY WORDS: Sediment Supply, Inadequate, Subsidence, Sub-Recent, Wide Lagoon, Patch-Reefs, Secondary Formation, Pocillopora damicornis, Acropora spp., Montipora spp., Turbinaria spp.,

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Introduction

The major coral formations of the territorial waters of India are centered around the Andaman and Nicobar Islands in the Bay of Bengal, along the main land coast in Palk Bay and Gulf of Mannar and in the Lakshadweep in the Laccadive Sea. Some patchy growth of corals, as yet undescribed, also occurs in the Gulf of Kutch. While the reefs of Lakshadweep are atolls, the continental islands of Andaman and Nicobars have fringing reefs. The coral formations of Gulf of Mannar and Palk Bay include a discontinuous reef over 140 km in length extending from Tuticorin to Rameswaram Island (Fig. 1) (1). Patch reefs and fringing reefs also occur along the coast of Rameswaram and Mandapam in Palk Bay. These formations are linked to the reefs of Ceylon by a shallow ridge, the "Adam's Bridge." Raised reefs at a height of 0.5 to 1.5 m from the present sea level are also found. Some of these living and raised reefs have already been described by Foote (2, 3), Sewell (4), Pillai (5, 6, 7, 8), Stoddart and Pillai (9), Reddiah (10) and Mergner and Scheer (11). The present paper deals with the structure and species diversity of these reefs, while attempting to postulate a hypothesis to explain their formations.

The Structure of South Indian Reefs

The major reef of Gulf of Mannar extends from Tuticorin (Long. 78°9'E, Lat. 8°48'N) to Shingle Island (Long. 79°14'E, Lat. 9°14'N). This formation rises from a shelf 25 km wide at a depth of 35 m (1). Scattered along the course of this reef are found 20 small islands (Fig. 1). The sea between the islands and the present mainland coast is 8-12 km wide and 5-15 m deep. The mainland coast is mostly sandy with occasional outcrops of sandstones. At Mandapam, the sandstones at the supralittoral zone are 1-3 m above the low water marks showing wavy solution surface at sites.

Patch Reefs in Palk Bay

On the Palk Bay side, along the Mandapam Peninsula, there extends a patch reef composed of intermittent blocks of laterite or granite, 0.5 to 2 m in greater spread with sandy interspaces. The reef crest, or the highest zone gets exposed at low tide. The lagoon is 400-600 m wide and 1-2 m deep at low tide. The innerside (lagoon side) of this reef harbours a wide variety of massive corals such as Porites, Goniopora, Siderastrea, Favia, Favites, Goniastrea, Leptastrea, Symphyllia and Turbinaria with occasional colonies of Acropora, Pocillopora

and Montipora. While there is comparative paucity of branching corals on the inner side, the outer side is luxuriant with Acropora and Pocillopora. This zonation of corals on this reef is the result of difference in the degree of sediment supply over the reef (7).

Inner Reefs

The patchy reefs on the protected sides of the islands in Gulf of Mannar have been investigated at several places by Pillai (6, 9), Mergner and Scheer (11) and Reddiah (10). These reefs are separated from the islands themselves by very shallow lagoon 200-500 m wide and 0.5-1 m deep at high tide with sandy bottom covered mostly by sea-weeds and algae with occasional patches of corals (8). The foliaceous Echinopora lamellosa and Montipora foliosa cut large platforms 1-3 m in diameter in deeper waters. A massive Porites zone in the northern islands with many Faviids is very conspicuous on the shoreward side. The very fact, the reefs are not consolidated into a compact structure seems to indicate their very recent formation than the reefs of the seaward side of the islands.

The Outer Reefs

The outer reefs on the leeward side are confined to the southern and southeastern sides of most of the islands. The reef flat at Karachalli Island (Long. 78°14'E, Lat. 8°57'N), the only one so far studied in some detail except those of the Appa Island, is separated from the shore by a shallow lagoon 50-250 m wide which drains at low tide. The lagoon bottom is strewn with dead corals and occasional living colonies of Porites and Turbinaria. Ramose corals such as Pocillopora damicornis, Acropora corymbosa and Montipora divaricata are also present. The reef flat gets exposed to a width of 150 m at low tides. The flat is not a much cemented structure, unlike those of the atoll reefs of Lakshadweep. The flat suddenly drops to deep waters where there is heavy wave action which prevents detailed observations on the outer edge. Several tiny pools, 1-3 m in spread with 15-30 cm of water, when the flat completely drains, are present all over. Living, but explanate coralla of Montipora foliosa along with stunted forms of M. divaricata and P. damicornis are present in the pools. The most common and abundant corals on the flat is M. divaricata which covers more or less 70% of the available space. The exposure of these thickets results in their death at the distal parts of the colonies, over which forms a thick encrustation of calcareous algae of brown color. Well

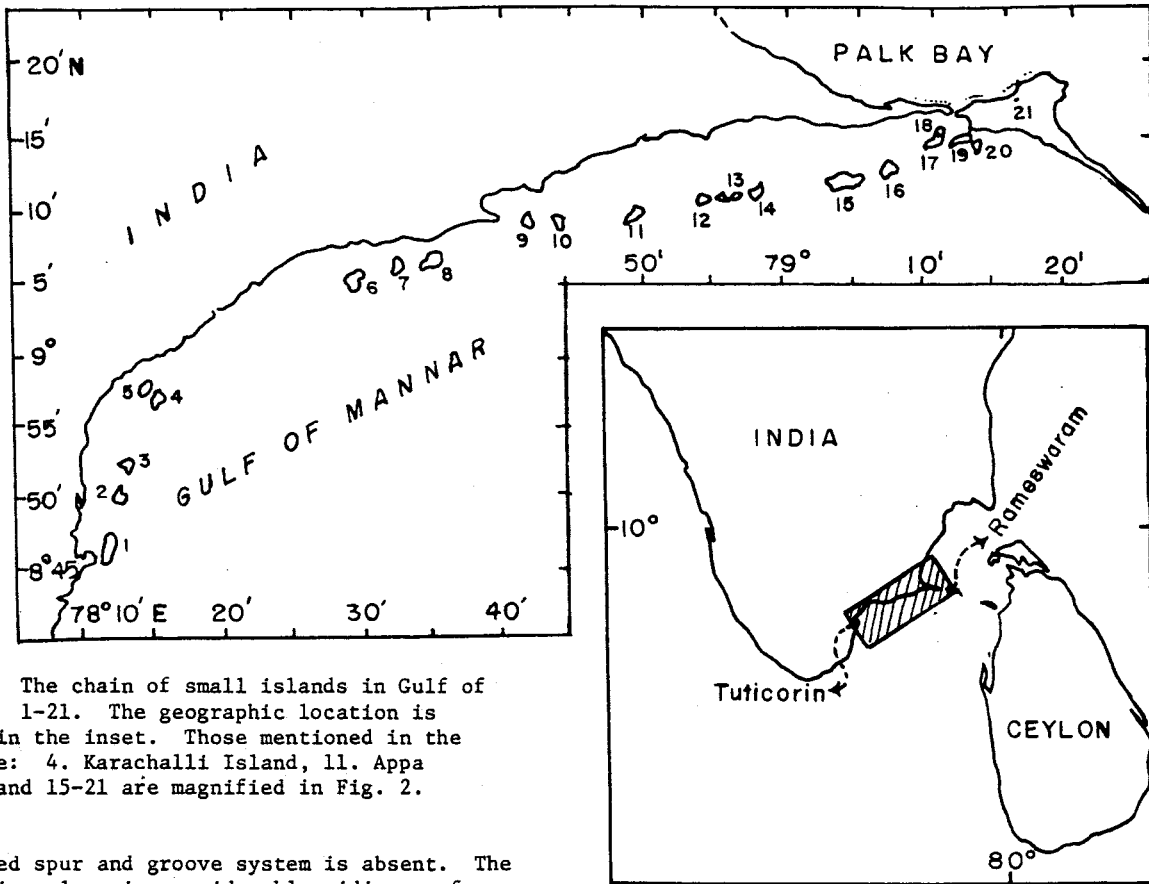


Fig. 1. The chain of small islands in Gulf of Mannar. 1-21. The geographic location is shaded in the inset. Those mentioned in the text are: 4. Karachalli Island, 11. Appa Island and 15-21 are magnified in Fig. 2.

developed spur and groove system is absent. The encrusting algae is considerably aiding reef building in this island, a feature not much significant at the northern islands around Rameswaram. There is a paucity of massive poritids and faviids on the southern islands as seen in Karachalli Island.

Islands

The reef islands and cays on the reef flats are an integral part of the reef complex, both in structure and formation, and any discussion on the geomorphology of the reefs without due consideration of them is likely to be incomplete. The nature and number of the south Indian islands have already been mentioned and they run almost parallel to the coast. Stoddart and Fosberg (1) described the zonation of plants and gross morphology of some of these islands. But as to the formation, very little is so far written. The nature of these islands as to depositional or continental is also little discussed in the literature. Detrital islands normally develop on reef flats by wave action and fall into two categories as sand cays and sand shingle cays (13). The present author in the course of his numerous visits to these islands near Rameswaram has had occasion to examine the soil and sub-surface layers to some extent, though no deep core studies could be made. From the remarkable similarity of the surface features of the islands

with that of the mainland an assumption could be made that they are of continental nature. The islands are more or less of the same elevation of the mainland, the surface sand being fine grained. The wave action on these islands are not sufficient enough to attribute a detrital origin to them (1). There is very little accumulation of shingle on the shores. Mangroves are present on the northern islands (Fig. 2) though absent at the adjacent mainland. No mangrove is seen in Karachalli Island when the mainland is full of low wooded *Avecenia marna*. Generally, elevated sandstones and rocky outcrops are absent on the islands except at Rameswaram Island and Appa Island, while such outcrops are present at many places along the continental coast. The sandstone formation of Appa Island is more or less similar to those of mainland (10). The absence of any large land vertebrates may be due to the fact that these islands are too small to support them.

Raised Reefs

Raised reefs of considerable magnitude (Fig. 2) are present in many places along the coast of Ramanathapuram District (9). There is an outcrop extending over 1 km at Manicardu Point

at Mandapam along Palk Bay and similar ones are seen along the northeast of Rameswaram Island. These exposures range from 0.5 to 1.5 m in elevation from the sea level. In some places as in Mandapam and Rameswaram, these reefs extend far into the island and are covered by sand and vegetation, mostly of *Acasia* sp. and *Borassus flabellifer*. The raised reefs of this area are faunistically similar to the present day living reefs (9).

Formation of the Reefs and Reef Islands

The Role of Subsidence

For reasons given above, one is led to the assumption that the tiny islands of Gulf of Mannar have a continental origin similar to Andaman Nicobar Islands. The east coast of India has been invaded by sea again and again from the Jurassic to Mid-pleistocene, though the broad outlines of the coast might have been determined in Cretaceous (14, p. 38). Vast stretches of land along the east coast underwent subsidence many times till Pleistocene along with a few minor secular movements resulting in a relative change in the levels of sea and land (14, p. 38; 15). Such a phenomenon of sinking appears to have taken place in many parts of the Indo-Pacific such as Madagascar (16, 17), Mergui Archipelago (14), East Indies (18) and East Coast of Australia (19-25).

It is possible that a fringing reef bordered the southeast coast of India prior to sinking of the coast sometimes in late Pleistocene or early Holocene. The sinking may not have been uniform, the higher parts of the land at the area of the reef remained at a higher level forming a shelf on which the present day islands rest. These shelves could have been with many submerged cliffs. Upward and outward growth of corals further continued at the seaward side of these submerged cliffs for some time.

A simple subsidence and subsequent growth of corals as postulated by Darwin (26, 27) alone appears not to account for the gross features of the reefs and islands of this region. The raised reefs as well as elevated sandstones are clear indications of a relative change in the levels of land and sea. A subsidence followed by a much latter uplift of local nature seems to explain the formation of both present day outer reef flats and islands. Two aspects of geological happenings have to be considered in an attempt to explain a relative change in the levels of land and sea in an area: 1. lowering of the sea level, and 2. a tectonic uplift.

A Lowering of Sea Level

The reefs of the Indian Ocean have been built almost entirely during Tertiary or

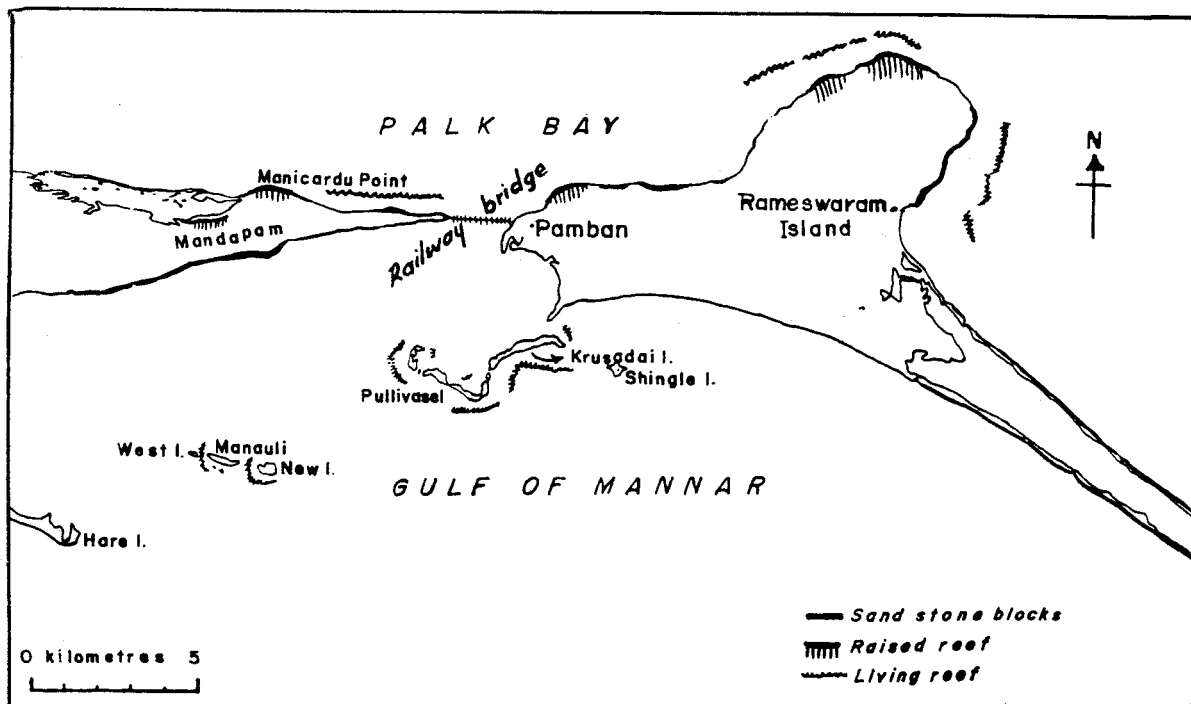


Fig. 2. Rameswaram and adjacent islands at the northern end of Indian reef formations.

Quaternary and the present surface features represent the erosional and depositional consequences of Pleistocene and Holocene sea level fluctuations (20, p. 60). A Holocene high stand of the sea followed by a fall in the last 5000-3000 year B.P. was sought as plausible explanation to the presence of elevated reefs throughout the Indo-Pacific (29). Such an inferred negative movement of the level would expose island features and reefs (30, 31). Several authors in the recent past came for and against such a Holocene high stand in the sea. Recently Maxwell (19) discussing the geomorphological features of Eastern Queensland, summarized data to argue that evidences are in support of Holocene highstand of the sea. However, Stoddart (31) could not fully agree to the concept after examination of radiometrically determined ages of many reefs of the Indo-Pacific. A sample of *Porites* from the raised reefs of Pamban (elevation 0.5 m) was shown to be 4020 ± 160 yr B.P. (9) while Hubbs *et al.* (after 9) determined the age of a sample from Hikkadavu, Ceylon (elevation 0.6 to 1.m) to be 2919 ± 220 yr B.P. Because of this disparity in the ages of samples from the two adjacent areas Stoddart and Pillai (9) suggested that the raised reefs of south India are the results of local geologic disturbances.

Local Tectonic Uplift

Raised reefs occur at a few places in the Central Indian Ocean such as Ceylon, Andaman and Nicobar Islands (33), Ramanathapuram District and Minicoy (33). A recent examination of the Kiltan Island in northern Lakshadweep by the present author showed elevated reefs to a height of nearly 3 m from the sea level. Though few hypogene disturbances have interfered with the stability of Indian Peninsula as a continental land mass for an immense length of geological time, there have been movements of secular upheaval and depressions in the recent time (14). In the absence of any conclusive evidence for a lowering of the sea level during the last 3000-5000 yr, it is safe to assume that a local upheaval of tectonic nature within this period has caused the emergence of the raised reefs and islands in this area. This resulted in a relative change in the levels of sea and land to the tune of 1.5 m (4).

Formation of Inner Reefs

As the sea level lowered, due to uplift of the area, the submerged cliffs bordered by the reef emerged as islands. The inner protected side of the bay had exposed hard substratum of laterite and sandstone on which coral planulae could settle. The very patchy nature of the coral growth suggests that it is of a recent origin. Erosion by wave action could have caused further exposure of base rock. An earlier reef that existed prior to the tectonic uplift

remains as the raised reef along Palk Bay. The inner patch reef is positively of a very much younger formation than the seaward reefs of the islands.

Erosion and Separation of Islands

Erosion by wave action and occasional cyclones might have played a significant role in separating many small islands in this area. The very shallow nature of the sea in between, and the proximity of the islands may indicate the presence of continuous land between some islands, soon after emergence.

Species Diversity

The coral genera of the various Indo-Pacific areas are mostly the same except for certain minor elements such as *Siderastrea*, in the western and Central Indian Ocean; *Oulastrea* and *Coeloseris*, in Andaman Nicobar Islands, East Indies and Great Barrier Reef area (34). A total of 96 species of hermatypes divided among 26 genera (9) are hitherto recorded from the South Indian reefs along with 10 species of ahermatypes. The common Indo-Pacific genera such as *Pocillopora*, *Acropora*, *Montipora*, *Astreopora*, *Favia*, *Favites*, *Goniastrea*, *Leptastrea*, *Porites*, *Goniopora*, *Platygyra*, *Symphyllia* and *Turbinaria* are represented and genera such as *Fungia*, *Podabacia*, *Sandalolitha*, *Poliphylia* and *Herpolitha* are not known even after several years of intensive collecting.

The composition of the coral fauna of any single island, as well as in the patch reef of Palk Bay is remarkably uniform at generic level. Zonation of any kind based on particular species dominance is indistinct, though generally small-polyped *Acropora* and *Montipora* dominate at the outer deeper, cleaner waters of the reef, while large-polyped faviids and some poritids colonize at the shoreward side (7). However, there appears to be a notable difference of the various species of the same genus occurring on different localities. This is much more distinct at a north-south direction, though, latitudinal difference could not be clearly made out. In the Southern islands near Tuticorin the most dominant element is *Montipora divaricata* on reef flats and lagoon with *Turbinaria undata* in lagoon. *Acropora* is represented by only three or four species and is not very conspicuous. The massive *Porites* is represented by *P. lutea* and *P. lichen* but is not a major reef builder. In the northern islands (Fig. 2) *Porites* is very conspicuous and forms the basis structure of the reefs. Faviids are also of importance. *Acropora* is rich and covers a good portion of the available space and at least 8 species could be collected from a limited reef tract.

Only a single, viz. *Montipora divaricata* community with *Acropora corymbosa*, *A. formosa*,

Pocillopora damicornis and occasional colonies of Porites and Turbinaria is recognizable near Tuticorin, while, at least three coral assemblages could be made out at the northern islands as follows: 1. Acropora community. This is represented by ramose, caespitose, flabellate and arborescent Acropora, chiefly A. formosa, A. nobilis, A. haimei, A. plantagenea (= humilis), A. corymbosa, A. hyacinthus and A. millepora (= surculosa). Montipora spp. and Pocillopora spp. are also seen. Poritids and faviids are not significant among the Acropora community. This assemblage is characteristic of the outer slope of the reefs. 2. Porites community. Porites is represented by about 12 species in the northern islands most of which are omnipresent and the genus is very abundant in the number of colonies. Dead colonies afford substratum to many faviids and astrocoeniids. The Porites community is very rich in the reef and inner sides where there is a comparative reduction in Acropora community. 3. Echinopora community. Echinopora lamellosa mixed with Montipora foliosa cut large platforms 1-3 m in diameter at the deeper waters, sometimes intermittent with Acropora assemblage. On the top of such platforms most of the common corals of this area are found growing, wherever there is dead surfaces. However, none of the genera are conspicuous among Echinopora - Montipora foliosa assemblage.

In general, the northern islands harbour a richer and more diverse coral fauna than the southern end of Mannar reef. The total number of species range from 30 to 60 in various islands in a south-north direction.

Synthesis

The above assessment postulates the following geological events in the formation of the reefs and islands in the south-east India.

1. The 20 small islands are of continental nature.
2. The mainland of India along the east coast was subjected to considerable subsidence at many times in the geological past.
3. The higher areas of the sunken land remained as a submerged ridge with many cliffs.
4. A fringing reef developed on the seaward side of the submerged ridge which grew outwards and upwards.
5. Evidence obtained from the raised reefs are not in full support of a Holocene highstand of the sea here which could have allowed reef growth at a higher level than the present.
6. A recent tectonic uplift within 5000 yr B.P. caused an elevation of the area of 1.5 m causing the emergence of the reefs and the islands.
7. The uplift of islands and the reefs accelerated erosional activities and the present day outer reef flats were levelled.
8. A secondary reef formation, much younger, was started at the protected side of the islands and along the shores of Palk Bay which are the present day patch reefs. This growth possibly began after the relative change in the levels

of land and sea due to uplift, when base rock was exposed. 9. No single geologic event seems to account for the geomorphological features of the reefs and islands of this area ; but an interplay of subsidence, uplift and erosion.

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