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*Sea Level Variations: Evidence from Sri Lanka and South India**

Jinadasa Katupotha

Introduction

During the last glacial maximum (LGM), ca. 18,000 yr B.P. ago sea surface circulation patterns of the India Ocean were significantly different from the modern patterns (Prell et.al. 1980). Due to increased continental aridity as well as increased intensity of winds during this period, the amount of quartz transported in the form of atmospheric dust from the Arabian and Australian deserts into the adjacent oceans was greater than that at present (Kolla and Biscave, 1977). The combined evidence from rivers, dunes, loess and pollen spectra indicates a drier and windier climate towards 18,000 yr B.P. over much of tropical Africa, Australia and India, with less rain in summer and stronger winds in winter monsoon months (Williams, 1985). Hence, at this time, the sea-level was prograded several kilometres beyond the present shore forming erosional and depositional surfaces around Sri Lanka and India. The present continental shelf between one hundred fathom (180 m) and ten fathom (ca. 20 m) isobars is a drowned extension of the land (Deraniyagala, 1958). This area is characterized by former river courses, lowlying ridges, troughs, terraces and rocknobs. These are covered with marine features such as coralline algae, limestone and calcareous sandstone and submerged forests. According to Wayland (1919), the Red Earth formation on the northern coastal lowlands of Sri Lanka has been deposited by aeolian processes when desert-like conditions existed over much of the low country. Deraniyahala (1986) regards the basal gravel overlain by dune sands distributed along the lowlands of north western and southern coasts as the result of altithermal episodes during the late Quaternary.

Recently obtained C^{14} dates from inland buried and emerged coral reef patches along the SW and south coasts indicate that there were two different age groups related to high sea-level episodes, viz 6, 170 $\pm$ 70–5,100 $\pm$ 70 yr B.P. and 3, 210 $\pm$ 70— 2,330 $\pm$ 60 yr. B.P. Based on above dates, it is possible to suggest that the PGT culminated ca. 5, 350 $\pm$ 80 yr B.P. and that the mid-Holo cene sea-level was at least 1 m above that of the present level (Katupotha, 1988a; 1988b; 1988c;). As evidenced from C^{14} dates of shells cemented with beachrock on the west coast and also from emerged shell deposits of coastal embayments along the southern coast, in can be suggested that a slight lowering of sea-level had occurred between these two episodes (Katupotha and Fujiwara, 1988).

Reprinted from Sea Level Variation and its Impact on Coastal Environment (ed. G. Victor Rajamanickam) Tamil University, Publication No. 131 (1990) Thanjavur.

Sea-level changes that followed the palaeoclimatic variations have had an impact particularly on the coastal zones and environment of Sri Lanka, India and adjacent island. There is a need for research on sea-level changes since the LGM which compares the evidence from Sri Lanka with similar evidence from ancient coastal deposits of Tamilnadu in South India and other Indian Ocean and Pacific reefs. They are of vital importance to study the present and future influences on climatic changes, sea-level variations and formative processes of landforms, distribution of sediments, fauns, flora and Pre-historic cultures. This paper compares the sea-level variations of Sri Lanka that followed during the PGT with that of events at the same period from South India on the basis of available data.

Study Area

Coastal lowlands and the continental shelf around Sri Lanka and South India were selected to examine the sea-level variations and their impact on coastal Zones and environment (Figs. 11.2 and 11.2). The continental shelf and the coastal lowlands of Sri Lanka have been subjected to recent changes of sea-levels and consist of different types of landforms (Katupotha 1988c: 1988d). Submerged coral reefs, sandstones, emerged and buried coral deposits are well-known indicators of sea-level variations in tropical coasts (Hopley, 1987; 1988, Pirazzoli and Montaggioni, 1988). Similar marine features such as former river courses, lowlying ridges, troughs and terraces, and rock outcrops that have been covered by coralline algae, limestone and calcareous sandstone reefs and submerged forests exist on the continental shelf around Sri Lanka and between Sri Lanka and South India. In many areas along the southwest and south coasts, old buried corals and shell deposits extend from the present shore to 250m inland and sometimes up to several kilometres towards the interior. They have been laid on the lateritized and weathered crystalline rocks. Fossil coral reef patches and shall deposits also occur a few metres above the mean sea-level.

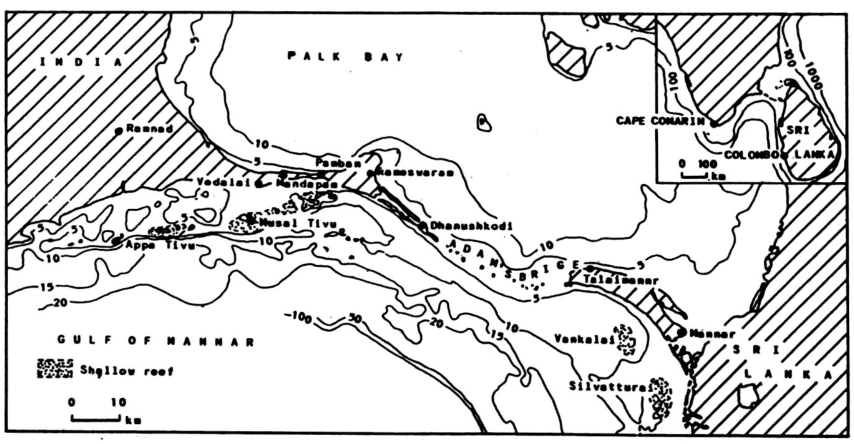

Fig. 11.1 : Shallow reefs between Palk Bay and Gulf of Mannar (after Stoddart and Pillai, 1972.)

The coral reefs in Sri Lanka are predominantly of the fringing type. These formations occur along the western coast from Kalpitiya to Colombo, along the southwestern coast from Ambalngoda to Matara, along the southeastern shelf from Great Basses and Little Basses, along the eastern coast from Kalkudah to Periyamunai Point (Baticaloa), along the notheastern coast form Trincomalee to Mullativu and along the northern coast around Keeramalai. Two barrier like reefs also occur at Venkalai and Silvaturai along the northwestern coast, south of the Mannar island (Fig. 11.3.) In these areas are to be found dead and living coral reefs in the nearshore areas and old buried corals and emerged coral reef patches along the coastal lowlands.

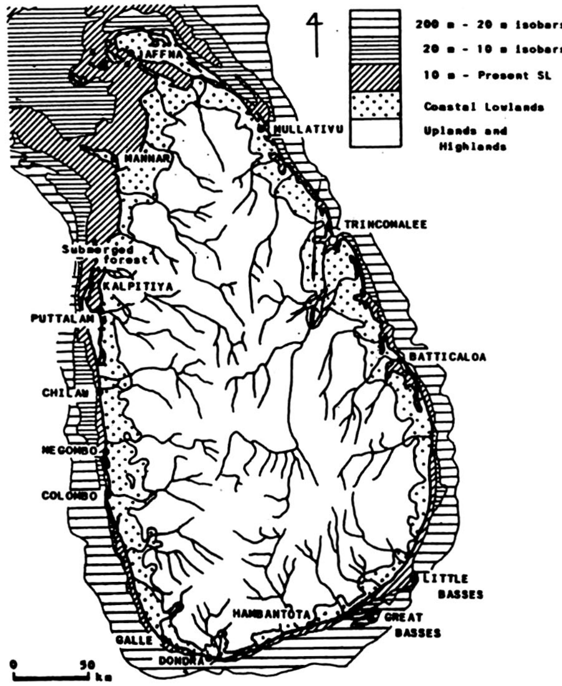

Fig. 11.2 : The extent of continental shelf coastal lowlands of Sri Lanka. (1) Evidence of submerged troughs and terraces, channels of some larger rivers and well-marked coral and sandstone reefs, and submerged forests exist between 200 m and the present SL. (2) The coastal consist of extensive buried coral deposits, emerged coral reef patches, shell deposits, and Red Earth (Katupotha, 1988e).

On some parts of the Indian coast and Indian Ocean remarkable coral reefs occur in the tropical island of the Laccadive Minicoy and Amindivi in the Arabian sea, and the Andaman and Nicobar archipelago in the Bay of Bengal. The Laccadive group consists of a number of coral atolls. Near the mainland only few reefs are being built by living corals at present (Ahmad, 1972). Old coral deposits, however, are found in a number of localities. A series of old beaches and inland coral reefs of the Saurashtra coast provide evidence for variations in sea-level during the mid-Holocene and the late Pleistocene (Gupta, 1972, Somayajulu et al., 1985). Between Cochin in Kerala and the Adam's Bridge, coral reefs of various length and sizes can be identified. The Adam's Bridge is a long barrier from Pamban Island to NW Sri Lanka built by single sandstone pillars covered by corals. This indicates evidence for the rise of sea-level during the PGT. The occurrence of numerous offshore submarine coral banks and emerged reef patches between Palk Strait and the Gulf of Mannar point to relate the existence of more favourable conditions of the alternating monsoons and to the rising sea-level (Chatterjee, 1963; Stoddart and Pillai, Mergner and Scheer, 1974).

Results and Discussion

Prell et al. (1980) who summarized the surface circulation patterns of the Indian Ocean showed that they were significantly different from the modern patterns during the height of the LGM, approximately 18,000 yr B.P. ago e.g. (1) The polar front was 5^0 to 10^0 latitude further north to its present location. (2) The Subtropical Convergence zone also was about 2^0

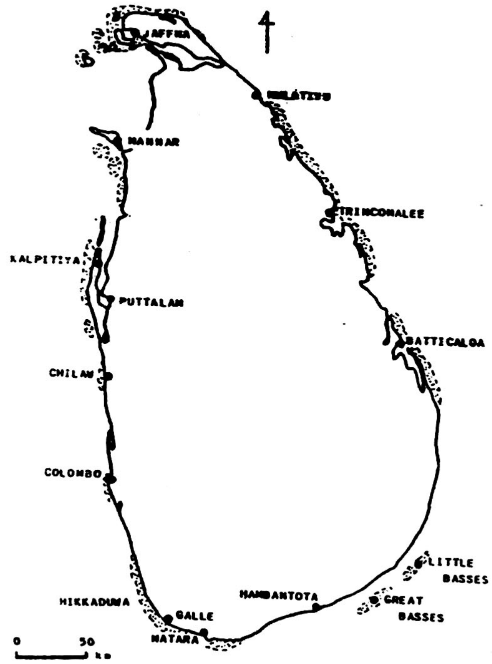

Fig. 11.3 : Distribution of coral reefs around Sri Lanka.

latitude further north of the western Indian Ocean and about 5^0 latitude north in the eastern Indian Ocean. (3) The West Australian current was more intense due to the deflection of the West Wind Drift northward along the coast of Australia. (4) The Agulhas current was weaker in the summer with a shallow tropical flow poleward and more subtropical during the winter. The Agulhas current was cooler at all seasons. (5) The low latitude gyre and equatorial regions exhibited very little temperature changes. (6) Decreased upwelling in the Arabian Sea and higher salinities in the Bay of Bengal indicate that the Southwest monsoon was weaker. (7) On the average, during the LGM, the Indian Ocean was 1.9^0C cooler in February and 1.7^0C cooler in August. Based on X-ray diffraction analysis of 300 of the surface (Holocene) sediments from the Indian Ocean presented by Kolla and Biscave (1977), it appears that during the LGM, the aeolian influx of quartz into the Indian Ocean was higher than at present. This reflects increased aridity in the source areas as well as increased wind intensity during this period. Besides, Williams (1982 or 85) describes that towards 18,000 yr B.P. the salinity gradient in the Bay of Bengal was very much steeper than today, reflecting a drastic reduction in freshwater input from rivers. The combined evidence from rivers, lakes, dunes, loess and pollen spectra represent a climate that was drier, windier over much of India with less rain in summer and stronger winter monsoon winds. All those studies emphasize the fact that stronger aeolian process existed around the India sub-continent and fluvial process extended several kilometres beyond the present shore around Sri Lanka and India during the LGM.

Simplified physiographic features on the continental shelf and around coastal lowlands of Sri Lanka are shown in Figs. 11.2 and 11.4. Fig. 11.2 indicates a drowned extension of the land formed by both erosional and constructional processes. Wickramaratne et al. (1988) report that the western continental shelf consists of predominately sand sized particles, 2 to 0.067 mm in diameter, composed of lithogenic quartz and biogenic carbonates. Most shelf sediments were deposited in shallow water during the last low stand sea-level and recent sediments are found accumulating only in nearshore areas and on the continental slope.

During the above mentioned period, the outer shelf area was starved of sediments due to their removal through submarine valleys canyons. This has resulted in the absence of calcareous skeletal material in the outer shelf area.

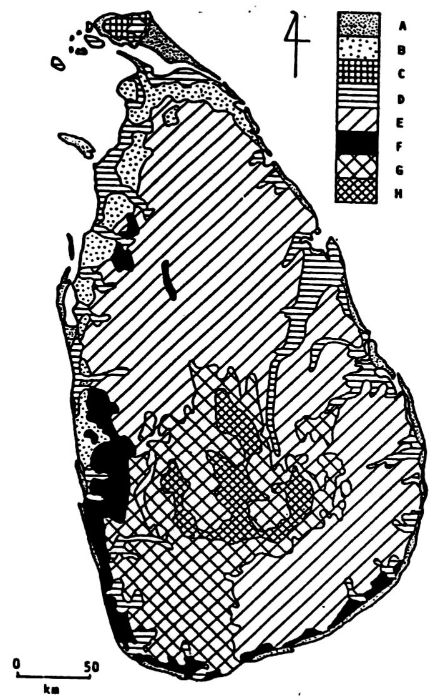

Fig. 11.4 : Simplified landforms map of Sri Lanka (after Swan, 1982). A: Holocene beaches and sand dune B: Old beaches; C: Limestone lowlying platforms; D: Fluvial, deltaic and marshy lands and associated water bodies; E: Undulating terrains; F: Low hills, ridges and terraces; G: Steep scarps, ridges and associated plateaus; H: High plateaus and plains.

The post-glacial transgression (PGT) appears to have started around 17,000-18,000 yr B.P. from about—80 m in many tropical and Mediterranian coasts (Fairbridge, 1961; Walcot, 1972; Pirazzoli, 1987). Fairbridge (1961) has reported that the sea-level remained about 3-5 m higher than at present during the period around 6.000-4,600 yr B.P. and with minor oscillations which continued later. On the basis of weathering conditions, colour, constituents of the sand and height of the beach ridges, four stages in the evolution of western coastal lowlands of Sri Lanka were identified by Katupotha (1988d) as follows (1) Stage I: from late Pleistocene to early Holocene. According to Wayland (1981) desert like conditions occurred in much of the low country, and low hills and ridges were coated mainly by wind blown sand during this period. This wind blown sand has been designated as 'Red Earth'. Archaeological sites of the coastal lowlands showed that the implements of early stone-age (Paleolithic) man were overlain by these deposits Marine features such as low-lying ridges, will-marked troughs and terraces on the inner and the outer shelves had been formed. During this period, the coralline algae, limestone and calcareous sandstone were developed gradually on those features due to rapid rise of sea-level from about 17,000 yr B.P. This transgression caused the rivers to fill their valleys and discharge their loads over the drowned peneplain. The desert-like conditions, during the LGM, of the low country can be correlated with the Pleistocene aridity in tropical Africa Australia and Asia. (2) stage II: Between mid-Holocene and the first phase of the late Holocene (6,600-3,700 yr B.P). Recently obtained C^{14} dates of geologic samples from the west and south coasts indicate that the mid-Holocene sea-level was at least 1 m above that of present level (Fig. 11.5). The existence of submerged forest in the northwestern shelf prove that the former coastal forest was drowned following this transgression. (3) Stage III: Late Holocene (around 3,7000 yr B.P.); It is suggested that the beachrock, slightly above the MHWS and ITZ, on the west coast formed during this stage. As evidenced from C^{14} dates of shell deposits along the southern coast in the Hambantota district coastal progradation has continued from the late Holocene (Katupotha, 1988c). (4) Stage IV: Recent beaches, sand spits, etc. All these formations from outer shelf to coastal lowlands have a close relationship with the sea-level variations which followed the low stand of sea-level during the LGM and the rise of sea-level during the PGT.

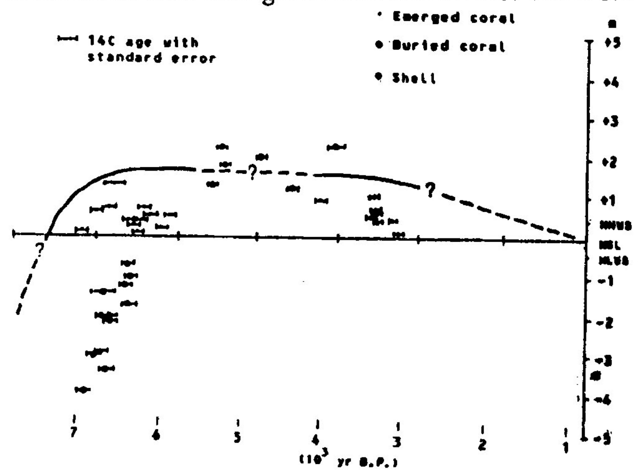

Fig. 11.5 : Mid and Late Holocene sea-level change in Sri Lanka (Katupotha and Fujiwara, 1988).

According to Mergner and Scheer (1974), the reef region of Mandapam in South India provides evidence of the influence of the alternating monsoon on coral growth and physiographic zonation. They have also divided the present living corals in the lagoon reefs on the nearshore zone, in front of Hikkaduwa, on the west coast of Sri Lanka into four zones from inland to sea, viz; shore; reef lagoon with inner reef-patches; outer barrier and littoral flat. They had originated either as a result of the gradual rise in sea-level or due to subsidence of the coast. It can be assumed that these present reef zone sequences were similar to physiographical and morphological patterns of palaeo bays or lagoons at Akurala (Fig. 11.6). Furthermore, three steps of a reef plate that exist to south of Hikkaduwa, could have been formed either as a result of the sealevel rise or due to contrary movements off the coast.

Stoddart and Pillai (1972) dated one emerged reef sample at Pamban at 4,020 $\pm$ 160 yr B.P. The other dates reported by Stoddart and Pillai (1972) from the Indian Ocean, with the exception of the Gulf of Agaba, are younger than the Pamban emerged reef (Table 11.1). Judging from the small number and the geographical scatter of these dates, more especially from the apparent absence of emerged reef deposits in the Maldives and Chagos archipelagoes in central Indian Ocean, Stoddart and Pillai (1972) suggested that the reefs which emerged during the period 5,000-2,000 yr B.P. were formed as a result of local rather than eustatic factors. On the other hand, recently obtained C^{14} dates from Sri Lanka support the concept of Holocene high stand of sea-level which followed the PGT.

On the basis of C^{14} dates from old beaches and dead coral reef along the Saurashtra coast on the westernmost India, Gupta (1972) identified two higher sea-levels during late Pleistocene and the mid-Holocene. The dated samples have been collected in their position of growth, and suggest that the old beaches and inland coral reefs were formed not as a result of uplift during recent times. As indicated by the archaeological evidence, Bedi and Rao (1984) describe a moist hot climate that prevailed in the area of Saurashtra coast during the period 6.000-3,000 yr B.P. During the period 5,500-3,500 yr B.P. the Pre-historic Harappa civilization was at its peak in parts of Gujarat. Therefore, Lothal was a port town during 5,500-4,500 yr B.P. situated at the top of Bhavnagar-Sabarmati creek with flourishing mercantile activity. Later it was deserted as the creek dried-up to coastal progradation. This process perhaps continued up to 2,500 when the climate became hotter and drier and later acquired the present characteristic.

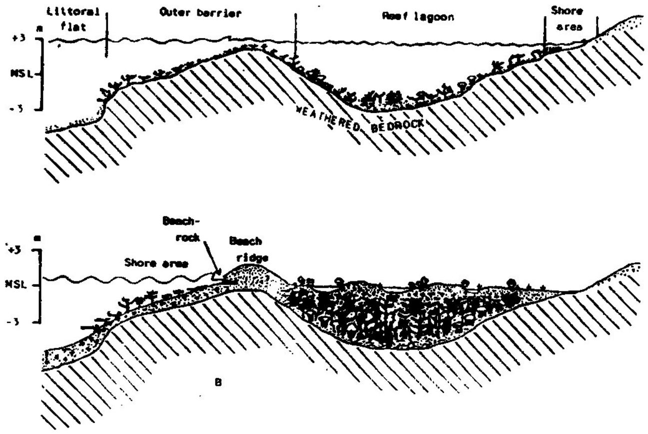

Fig. 11.6: Hypothetical profile of the bay or lagoon at Akurala. (A) Corals thrived in inland bays or lagoons following the PGT, and mid-Holocene sea-level was at least 1 m above that of present level. (B) The present position shows deposits of upright branching (*Acropora*) and massive (*Goniastrea, Goniopora, porites, etc.*) corals intermittently covered by various types of marine and fluvial sedimernts.

Thus, the above points to the fact that during LGM the climatic conditions caused the rivers to fill their valleys and discharge their loads over the drowned continental shelf around Sri Lanka and India. Furthermore, sea-level variations that occurred during the PGT is a result of eustatism. Archaeological evidence and folktales show that these variations have had an impact on Pre-historic civilizations along the coasts of Sri Lanka and India. Paleolithic tools of basel gravel overlain by Red Earth have been found in the present coastal lowlands of Sri Lanka. It is possible to infer that during the LGM, Paleolithic people had lived further sea-ward from the present shore. There is no controversy about the submergence of Paleolithic and Neolithic cultures following the rapid rise of sea-level during the PGT. Many evidence form the study area from Sri Lanka and South India, show that minor oscillations of sea-levels had continued after the PGT (late Holocene) which had an impact particularly on the civilized cultures along the coasts. Sometimes, these variations would have been a result of local rather than eustatism. The past experience of sea-level variations and their impacts are important to the study of present and future changes, of climate, sea-level, etc. and their effects on formative processes of land forms, fauna, flora as well as on man. Hence, it would be helpful to evolve a perspective plan on the sea-leave transformations and environment.

Conclusion

The combined evidence form landforms, the distribution of various types of sediments and artifacts indicate that a drier an windier climate had existed during the last glacial maximum (ca. 18,000 yr B.P). over much of the Indian sub-continent and other adjacent islands of the Indian Ocean with less rain in summer and stronger winds during winter monsoon months. Marine features such as well-marked troughs and terraces covered with marine sediments, sandstone reefs and submerged forest record the changes in the sea-level during the postglacial transgression. During the Mid-Holocene, the sea-level was above that of the present level, and submerged a large part of the present coastal lowland. The PGT submerged evidence of Neolithic civilization that existed in these areas as well as fauna and flora along the coasts of Sri Lanka and India. Minor oscillations of sea-level have continued after the PGT, during the late Holocene, with impacts particularly on Bronze, Iron and Roman age cultures. Research on past sea-leave variations and their impact to the coastal zones and environment as well as on man have a vital importance for understanding present and future influences.

Table 11.1 : Dated Buried corals, Emerged Reefs and Associated Shoreline Deposits in the Indian Ocean

No	Locality	Elevation (M $)	Age (yr B.P.) (half- life = 5568 ± 30)	Laboratory No.
(1)	(2)	(3)	(4)	(5)
	SRI LANKA			
	West Coast			
	(Chilaw)			
1.	Shell, (Fort- Colombo)	-1.5,	1680 ± 60,	HR 235,
2.	Peat	-0.3	700 ± 80	HR 271
	Southwest Coast (Akurala) (Coral quarry 1)			
3.	Coral	-1.4	5830 ± 90	HR 111
4.	Coral	-2.0	5820 ± 90	HR 112
5.	Coral	-2.9	5910 ± 70	HR 113
6.	Coral (Akurala) (Coral quarry 2)	-3.0	6000 ± 90	HR 114
7.	Coral	-1.7	5590 ± 80	HR 236
8.	Coral	-3.4	5840 ± 80	HR 237
9.	Shell	-0.3	Recent	HR 115a
10.	Coral	-2.1	5800 ± 80	HR 115b
11.	Coral	-3.9	6110 ± 80	HR 109
12.	Coral	-0.3 (SL)	6600 ± 500	
13.	Emerged coral	+0.5	5350 ± 80	HR 238
14.	Emerged coral	+0.1	6170 ± 70	HR 239
15.	Emerged coral	+0.7	5840 ± 80	HR 240
16.	Emerged coral (Hikkaduwa)	+0.6	5980 ± 70	HR 241
17.	Emerged coral	+0.5	5100 ± 70	HR 116
18.	Emerged coral	+1.0	3210 ± 70	HR 242
19.	Emerged coral	+1.0	2560 ± 60	HR 243
20.	Shell (Dadalla)	+0.6 to 1.0	2990 ± 220	Lj 207**
21.	Emerged coral	+0.2	5200 ± 70	HR 244
22.	Emerged coral (Mihiripenna) (coral quarry 3)	+0.1	5480 ± 70	HR 245
23.	Coral	-0.7	5600 ± 70	HR 246
24.	Shell	-1.2	5630 ± 70	HR 247
25.	Coral	-1.4	5970 ± 70	HR 248
26.	Coral (Habaraduwa) (Coral quarry 4)	-2.0	5910 ± 70	HR 249

(*Contd.*)

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(Table 11.1 *Contd.*)

(1)	(2)	(3)	(4)	(5)
27.	Coral South Coast (Koggala)	-0.9	5560 ± 70	HR 110
28.	Emerged (Koggala) coral (Aranwala)	+0.4	5440 ± 70	HR 250
29.	Emerged coral	+0.4	2330 ± 60	HR 251
30.	Emerged coral	+0.3	5540 ± 70	HR 252
31.	Emerged coral (Denuwala)	+0.1	2250 ± 60	HR 253
32.	Emerged coral	+0.7	2540 ± 60	HR 254
33.	Emerged coral	+0.5	2580 ± 60	HR 255
34.	Emerged coral	+0.6	2510 ± 60	HR 256
35.	Emerged coral (Palalla- Weligama)	+0.4	2520 ± 60	HR 257
36.	Shell	+1.8	4420 ± 70	HR 258
37.	Shell (Madihe-Matara) (Coral quarry 5)	+1.3	4560 ± 60	HR 259
38.	Coral	+0.1	4330 ± 60	HR 260
39.	Coral (Coral quarry 6)	-1.3	4850 ± 70	HR 261
40.	Coral	-0.1 to -0.03	4720 ± 60	HR 262
41.	Coral (Pallikkudawa)	-2.3	4830 ± 70	HR 263
42.	Emerged coral	+0.4	5610 ± 70	HR 269
43.	Emerged coral (Hungama)	+0.7	5470 ± 70	HR 270
44.	Shell	+1.3	5780 ± 20	HR 124
45.	Shell (Kalametiya)	+0.8	4440 ± 60	HR 264
46.	Shell	+1.2	3570 ± 60	HR 265
47.	Shell	+2.2	4460 ± 60	HR 266
48.	Shell (Karaganlewaya)	+2.0	3960 ± 60	HR 267
49.	Shell (Udamalala)	+2.3	3050 ± 100	HR 123
50.	Shell	ca. +6.5	4050 ± 60	HR 122
51.	Shell	ca. +5.0	4650 ± 70	HR 122
52.	GULF OF AQABA	0	4770 ± 140	-#
	MADAGASCAR			
53.	(Fencrive I)	+0.7 to 1.0	2930 ± 90	Gak 2161 #
54.	(Fencrive II)	+1.0 to 1.5	3740 ± 90	Gak 2162 #
55.	(Baie des Galions)	+1.1 to 1.4	2250 ± 420	-#
56.	(Itanpolo)	+0.5 to 1.6	860 ± 100	-#
	INDIA			
57.	Pamban	+0.5	4020 ± 160	Gak 3187 #

Sources: * Neef and Veeh, 1981; ** Hubbs et. al., 1964; # Stoddart and Pillai, 1972; other dates from Katupotha, 1988 a and 1988 b. § metre, SL—Surface level.

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