A NOTE ON THE COAST AND SHELF EVOLUTION OF SRI LANKA IN THE LATE QUATERNARY

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Abstract

The configuration and the bottom features of the continental shelf of Sri Lanka exhibit characteristics of a drowned extension of the land. Following the post-glacial transgression which began around 17,000-18,000 yr B.P. the sea had entered the lower portions of the river valleys forming drowned valleys which roughly extended up to the one hundred fathom isobar (ca. 180 m). The ten fathom (ca. 20 m) isobar appears to have become a coast line during a later stage. Sea-level indicators such as submerged channels of larger rivers, low-lying ridges and well-marked troughs and terraces found at different levels and drowned forests on the continental shelf confirm that there had been a low stand of sea-level during the last glacial period. It is suggested that the pre-Holocene Red Beds formation, which is widely prevalent on the coastal lowlands of the dry zone, has been deposited by aeolian processes. Therefore, 14C dates of geologic samples from western and southern coasts of Sri Lanka confirm that the relative sea-level was higher than at present during the mid-Holocene (Main Atlantic) and the Late Holocene (Late Subboreal).

Introduction

Various types of fossils have been used as sea-level indicators in the study of palaeo-sea-level changes of many stable tropical coasts (Van de Plassche, 1986). The island of Sri Lanka, situated in the Australian-Indian Plate, is considered as stable (Katz, 1978; Swan, 1982). Along the coasts of Sri Lanka, however, there is evidence to prove that changes in sea-level had occurred in recent times (Coates, 1935; Deraniyagala, 1958).

Submerged low-lying ridges, troughs and terraces which are covered by limestone and calcareous sandstone at different levels on the inner and the outer shelves and drowned forests on the nearshore zone provide evidence to support changes in sea level. Beachrock, buried and emerged coral-reef patches, emerged shell deposits and coastal barrier sand along the present coast also indicate that changes in the relative sea level had occurred in this region. These events can be correlated with the rapid rise in sea level since Last Glacial Maximum, from ca. 18,000 yr B.P. until 5,550 yr B.P.

14C dates from geologic samples of recent work indicate that the relative sea level has been higher than at present in the mid-Holocene and in the late Holocene (Hubbs et al., 1972; Neef and Veeh, 1982; Katupotha, 1988a; 1988b; Katupotha and Fujiwara, 1988). However, due to lack of detailed large-scale bathymetric charts and of facilities for collecting samples and radiometric datings, it is not possible to compare such changes in Sri Lanka morphologically and chronologically with those of recorded evidence of many other tropical coastal lowlands and continental shelves. This study focuses attention on the preliminary investigations undertaken by the author to examine the coast and shelf evolution in Sri Lanka based on bathymetric maps and other published evidence with special reference to the northwest, west and south coasts.

Study Area

The continental shelf around Sri Lanka is narrowest in the south, moderately wide off the west coast north of Galle and in the southwest and relatively narrow off most of the east coast. It becomes significantly wider in the north and northwest areas (Coates, 1935; Cooray, 1967; 1984). Wickramaratne et al. (1988) have divided the continental shelf and continental slope of western Sri Lanka into three parts, viz. (a) the nearshore zone (30 m), (b) the mid-shelf region (30-45 m), and (c) the outer shelf (45 m). These areas consist of low-lying ridges, well-developed troughs and prominent terraces, and large and small river valleys. They are covered by coralline algae, limestone and calcareous sandstone.

Extensive marine, lagoonal and estuarine deposits, particularly coral and oyster shells, occur up to 3 or 4 km inland from the present shore in several localities between Ambalangoda and Matara (southwest and south coasts) as well as from Tangalle to Kirinda (south coast). Upright branching and massive corals in the above-mentioned areas indicate that the corals have thrived in former bays or lagoons when the sea level was higher than at present. The coral rubble in some localities in these areas have been piled up under the minor oscillations of sea level in recent history. Furthermore, patches of fossil shell deposits have been found in many places along the rims of emerged coastal embayments and lagoon floors on the southern coast. Dunes in the area vary in size and are aligned in a SW-NE direction, according to prevailing winds during the monsoons.

The tides of Sri Lanka are micro-tidal, ranging from mean low water spring (MLWS) at -37 cm and mean high water spring (MHWS) at + 40 cm from the mean sea level at Colombo (data based on Colombo datum, Tide Tables Vol. 2, Indian and Pacific Oceans, 1987). This is somewhat larger than the range at other Sri Lankan stations. The location and extent and associated habitats of coastal landforms have a close relationship with this microtidal level.

Discussion

Simplified physiographic features on the continental shelf of Sri Lanka are shown in Fig. 1. Deraniyagala (1958) considered that the area between one hundred fathom (ca. 180 m) and ten fathom (20 m) isobars in Sri Lanka is the drowned extension of a peneplain in the third glacial phase. Evidence such as drowned valleys of some larger rivers, well-marked troughs and terraces covered with coralline algae, limestone and calcareous sandstone at different levels, and drowned forests on the continental shelf show that they have been formed on such a peneplain, following the marine transgression since Last Glacial Maximum. Wickramaratne et al. (1988) reported that the western continental shelf consists predominantly of lithogenic quartz and biogenic carbonates ranging from 2 mm to 0.067 mm in diameter. Most shell sediments had been deposited in shallow waters during the last low stand of sea level and recent sediments are found accumulating in nearshore areas and on the continental slope. During this low stand of sea level, the outer shelf area was starved of sediments due to their removal through submarine valleys and canyons. This has resulted in the absence of calcareous skeletal materials in the outer shelf areas.

Along the coast, the marine Miocene-Plio-Quaternary deposits exist as low cliffs under 30 m in height; a few km inland are esturine deposits of Holo-Pleistocene age (Deraniyagala, 1958). Such cliffs occur in the Arippu area southwards of Chilaw and recur at Minihagalkanda to the southeast and Kankesanturai in the north. Marine vertebrates have been identified as ***Malu*** deposit at Aruakalu 1.6 km to the south of Kala Oya mouth ***Labrodon sinhaleyus***. At Minihagalkanda the characteristic Miocene invertebrate is ***Ostera vireleti***, and the pearl oyster ***Pinctada vulgaris*** has been dug up 16 km inland at Madampe (Wadia, 1941; Deraniyagala, 1958).

The oldest accumulation on the coastal lowlands have been known as 'Plateau Deposits' by Wayland (1919), and sub-divided into two strata namely 'Red Earth' formation and 'Plateau Gravels'. The Red Earth is now renamed 'Red Beds' by Cooray and 'Iranamadu Formation' by Deraniyagala (1986). Well rounded, smooth and polished surfaces of the quartz grains of the Red Beds show that they are probably deposited by aeolian processes. On the other hand, the materials, composition and deposition pattern of the lower stratum of the Plateau Gravels reveal that the formation had been created by fluvial processes. According to Wayland (1919), archaeological sites of the coastal lowlands showed that the implements of early stone-age (Palaeolithic) man were overlaid by these deposits. These events have continued during the Last Glacial Maximum.

Geographical location, extent, composition, structure and evolution of the landforms which are formed during the Late Pleistocene and Holocene Epochs can be divided into four stages (Figs, 2, 3 and 4) ;:

(1) **Stage I**, from late Pleistocene to Early Holocene. According to investigations by Williams (1985), it is clear that dry, climatic conditions were formed in tropical Africa, Australia and Asia. Such climatic conditions were common in Sri Lanka, resulting in a wide coastal plain which provided the source of sand. By this means, parallel sand ridges on the northwestern and western coasts were formed, and the low hills and ridges were coated with wind blown sand. Such deposits can be identified as 'Red Beds' which rest on Ferruginous Basal Gravel or on Moicene Limestone, and to be 25,000 years old or more (Singhvi, 1986). These data help us to infer that the Ferruginous Basal Gravels and Terrace Gravel (Cooray, 1967; 1984; Deraniyagala, 1986), were formed during highly fluvial conditions before the Last Glacial Maximum.

The low-lying ridges, well- marked troughs, terraces and river valleys on the western shelves which were covered with coralline algae, limestone and calcareous sandstone and are included in Stage I, were formed during the rapid rise of sea level since Last Glacial Maximum (17,000-18,000 yr B.P.). In addition, a series of paralell, submerged beachrock reef in this area indicates former strandlines that were formed at palaeo sea levels (Fig. 5).

(2) **Stage II**, between mid-Holocene and the first phase of the Late Holocene (6,600-3,700 yr B.P.). The post-Glacial transgression rapidly occurred up to $6{,}170\pm70$-$5{,}170\pm70$ yr B.P. Inland buried and emerged coral reef patches along the coast thrived in inland bays and lagoons which followed that transgression; former coastal forests also were submerged. According to investigations by Katupotha and Fujiwara (1988), the 14C dates of buried and emerged corals which belong to this stage showed the occurrence of two episodes of high sea levels (Fig. 6). Likewise, one peat sample from a foundation pit at the Galadari Hotel Complex, near Beira Lake has been dated at $5{,}790\pm80$. This indicates that post-Glacial transgression culminated in a later period. Fine-to medium-grained sand in the upper layers of back barrier ridges which developed during this period were assumed to be wind blown in origin.

(3) **Stage III**, Late Holocene (around 3,700 yr B.P.). The beachrock slightly above the MHWS level and InterTidal Zone on the west coast belong to this stage. The beachrock at Pitipana-Negombo, above the MHWS level, has been dated at $2{,}470\pm70$ and $3{,}460\pm160$ yr B.P.(Katupotha, 1988a). These beachrock reefs are comparable to those in Brazil, Venezuela and other tropical coasts (Cooray, 1968; Katupotha, 1989). Distribution of shell deposits along the southern coast indicates that there had been a lowering of sea level along the west and south coasts after around 3,700 yr B.P. (Katupotha and Wijayanande, 1989); and that sea level was again higher than at present during the period between $3{,}210\pm70$ and $2{,}330\pm70$ yr B.P. (Katupotha, 1991).

(4) **Stage IV**, Late Holocene (Late Subborreal - since 3,700 yr B.P. to present). More 'humid' conditions than at present continued during the period between 3,100 and 1,800 yr B.P. Since then 'semi-arid' and 'arid'

phases can be seen up to the present. Beaches, barrier or sand spits and upper strata of the lagoonal and estuarine beds are present along the existing shoreline or immediately behind them. 14C dating at Chilaw (1,680 ± 60 yr B.P.) indicates that the shells are brackish forms which lived in the inter-tidal zone that was covered from base to top by coarse sand with pebbles (terrestrial?) and fine sand, respectively (Katupotha, 1988a).

All these features show a close relationship with eustatic events during the Late Quaternary (Table 1). During the low stand of sea level in the Last Glacial Maximum and during Early Holocene time, the climatic conditions caused the rivers to fill their valleys and discharge their loads over the sub-merged peneplain and coastal lowlands. During the Holocene Epoch the marine and fluvial formations were developed on the coast due to the changes of climate and oscillations of the sea level. These events can be easily corre-lated with investigations which were carried out in tropical coasts by Fair-bridge (1961) and others (Morner, 1982 and Pirzazzoli, 1986).

Conclusion

As a result of the marine transgression since Last Glacial Maximum (around 17,000 - 18,000 yr B.P.) the sea entered the lower portions of the rivers forming drowned river valleys. The sea level indicators such as sub-merged channels of some larger rivers, low-lying ridges, well-marked troughs and terraces at different levels and drowned forest on the continental shelf prove that there had been changes in the sea level during this phase. It is suggested that the Red Beds on the coastal lowlands had been deposited by aeolian processes following dry climatic conditions during the low stand of sea-level in the Last Glacial Maximum and before the Last Glacial Maximum. Buried corals and emerged coral reef patches along the coastal lowlands in-dicate that corals thrived in inland bays and lagoons in the mid-Holocene and the Late Holocene due to the high stand of sea level which was above that of the present level. Furthermore, the inland shell deposits along the southern coast which have been piled up mainly by wave action shows that a recession of the sea took place again, after the Late Holocene.

Acknowledgements

Grateful thanks are extended to Professor P. G. Cooray, Institute of Fundamental Studies, Sri Lanka, Professor (Mrs.) Y. A. D. S. Wanasinghe, Department of Geography, University of Sri Jayewardenepura, Sri Lanka and Dr. O. van de Plassche, Institut Voor Aardwetenschappen, Vrije Uni-versiteit, the Netherlands for reading the manuscript critically.

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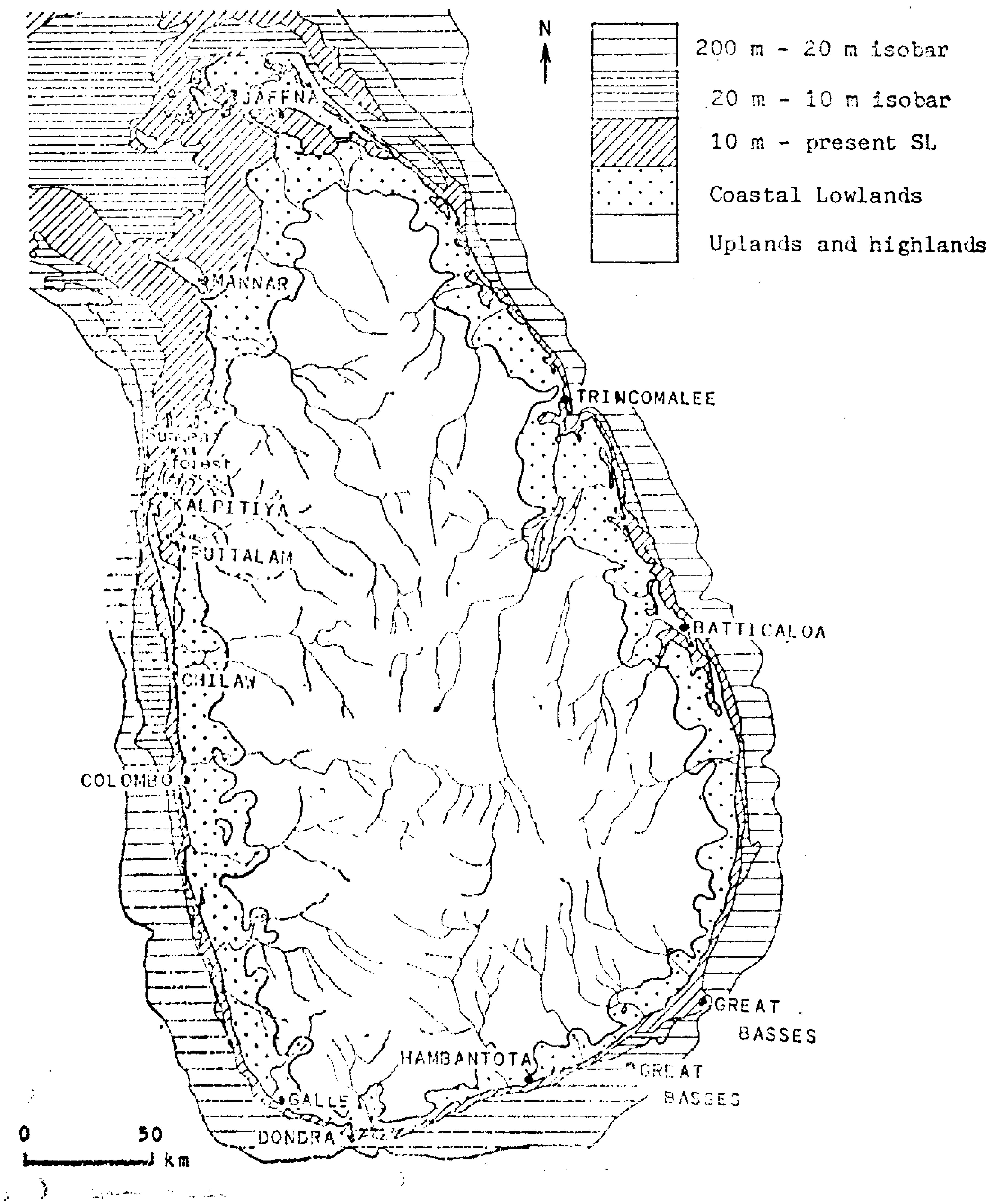

Fig. 1. Oscillation of sea level around Sri Lanka. 1) Evidence of sunken forests, submerged channels of some larger rivers and well-marked beach-rock and coral reefs can be seen between 200 m isobar and the present sea level. 2) The coastal lowlands consists of extensive buried coral deposits, emerged coral reef patches, shell beds and Red Beds (Katupotha, 1988c).

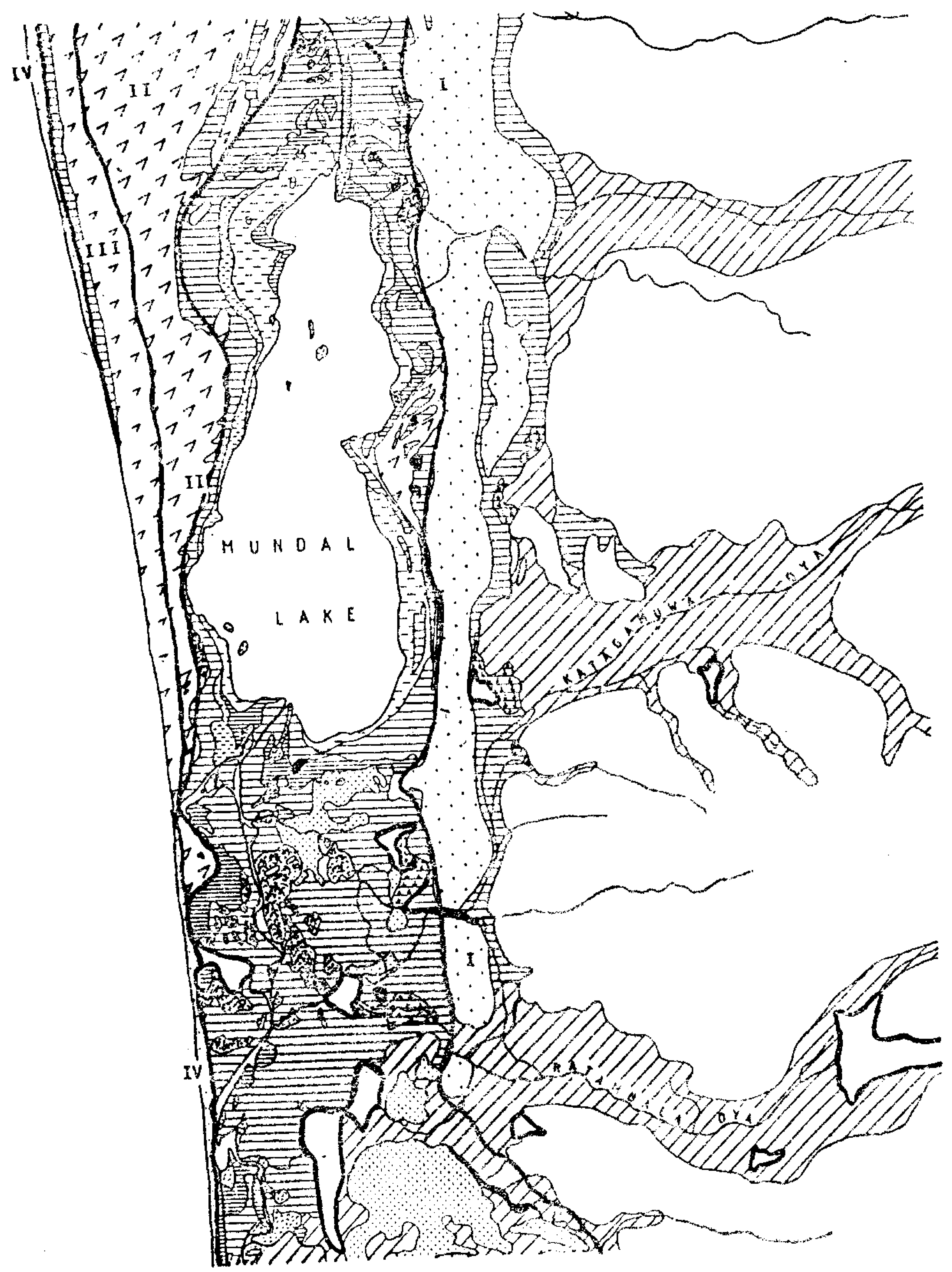

Fig. 2. Sketch map showing the evolutionary stages around Mundal Lake. (1) Stage 1, from Late Pleistocene to Early Holocene; (2) Stage 11, between mid-Holocene and first phase of the Late Holocene (6,600-3,700 B.P.) ; (3) Stage 111, Late Holocene (around 3,700 B.P.) ; (4) Stage IV, Modern. Similar stages are shown in Figs. 3 and 4 (Katupotha, 1988d).

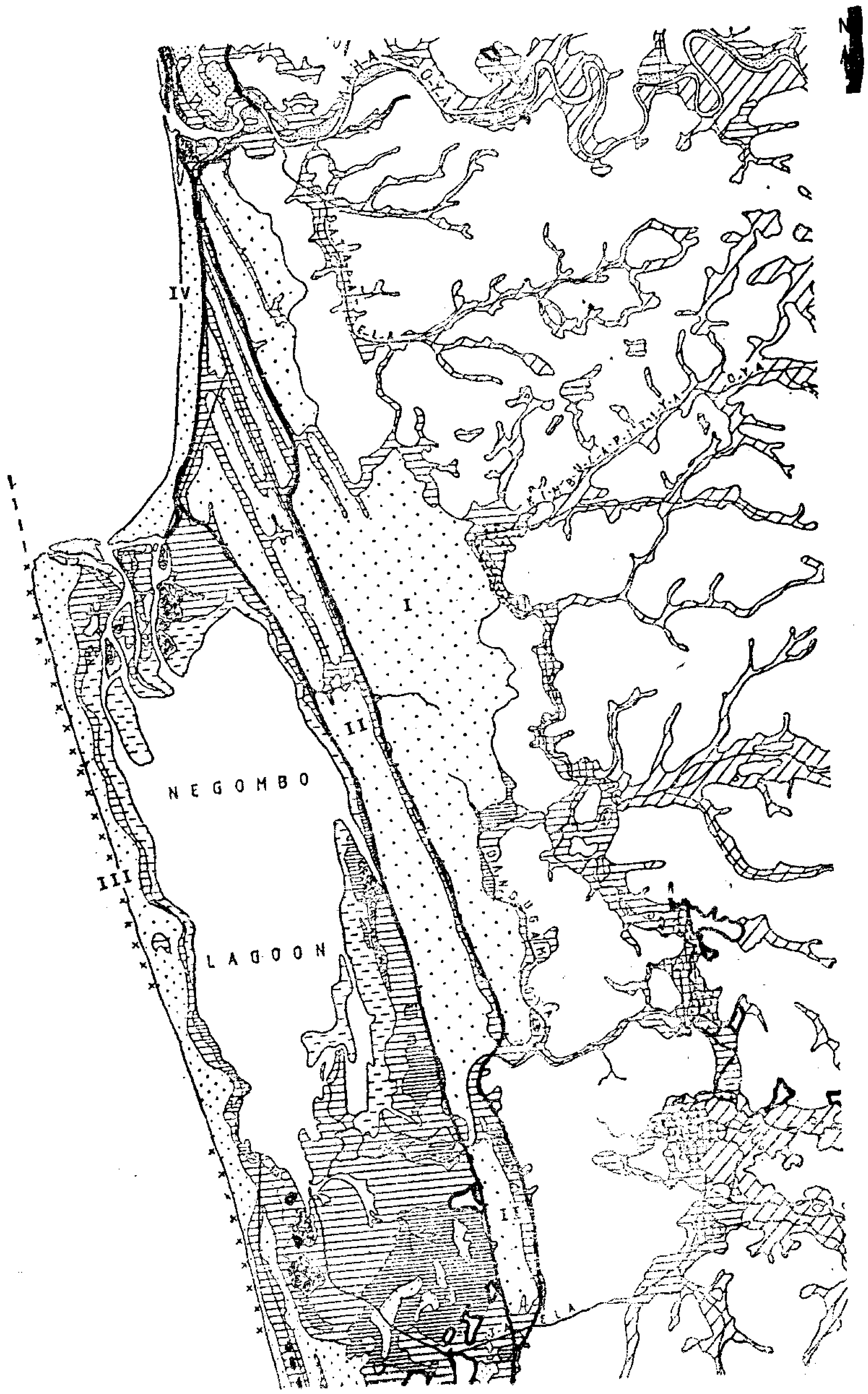

Fig. 3. Sketch map showing the evolution of sand ridges around Negombo Lagoon (Katupotha, 1988d).

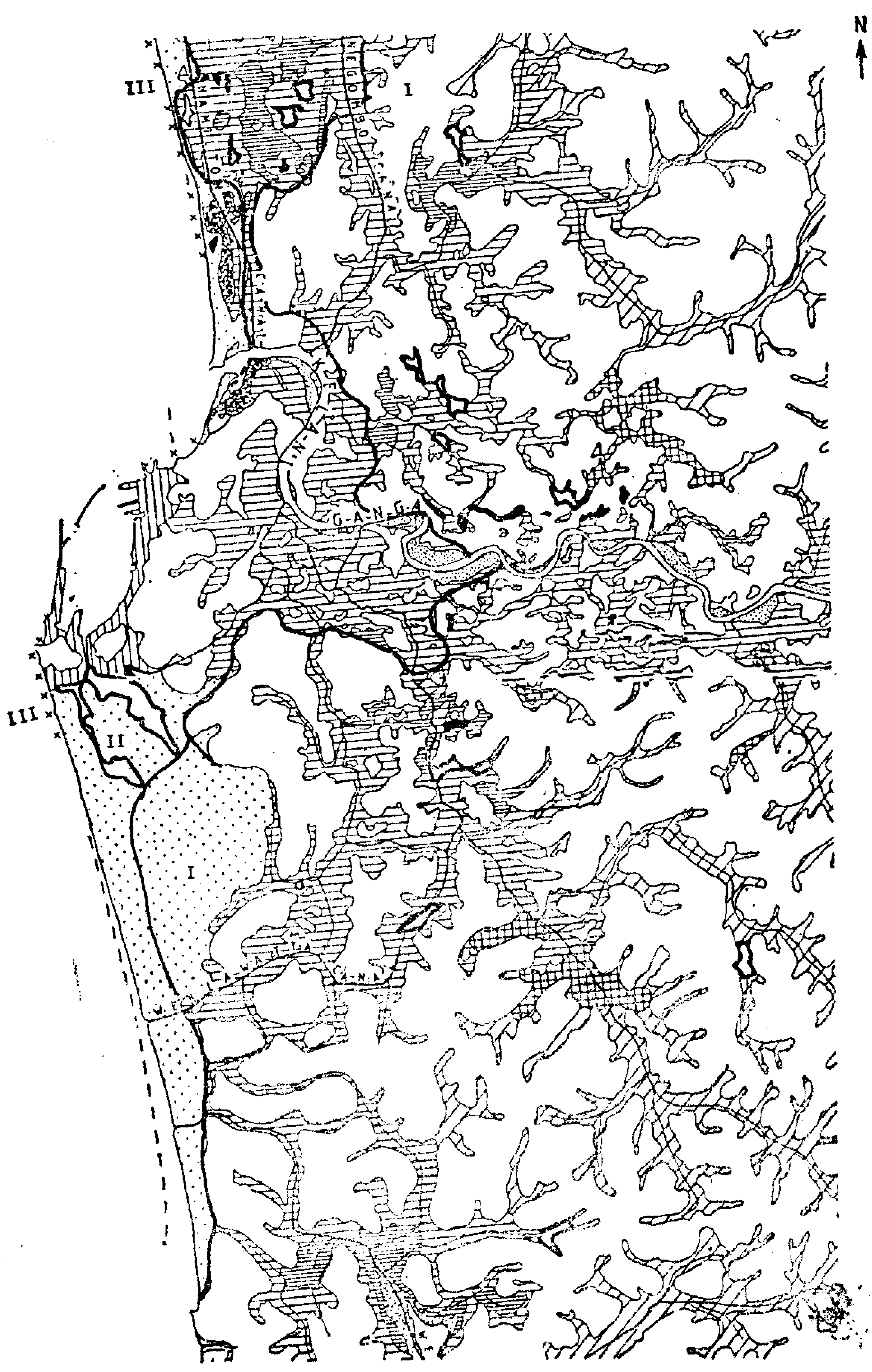

Fig. 4. Sketch map showing the evoloutionary stages around Colombo (Katupotha, 1988d).

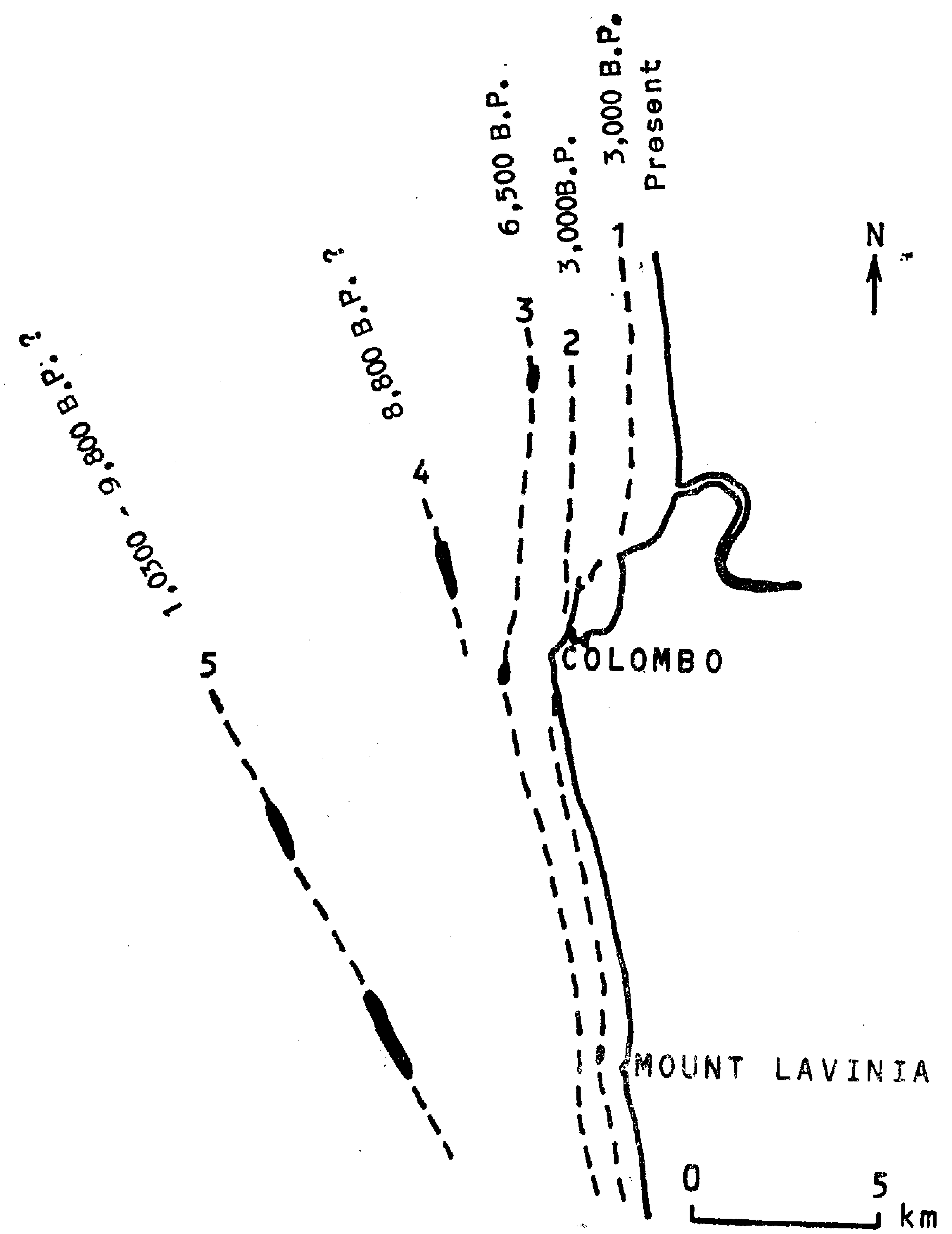

Fig. 5. (1) MSL ; (2) 0.5 to 1.5 m ; (3) 10 m ; (4) 17 to 18 m ; (5) 25 m below MSL. Possible ages of development of sandstone (beachrock) reef on the western continental shelf are made by Katupotha.

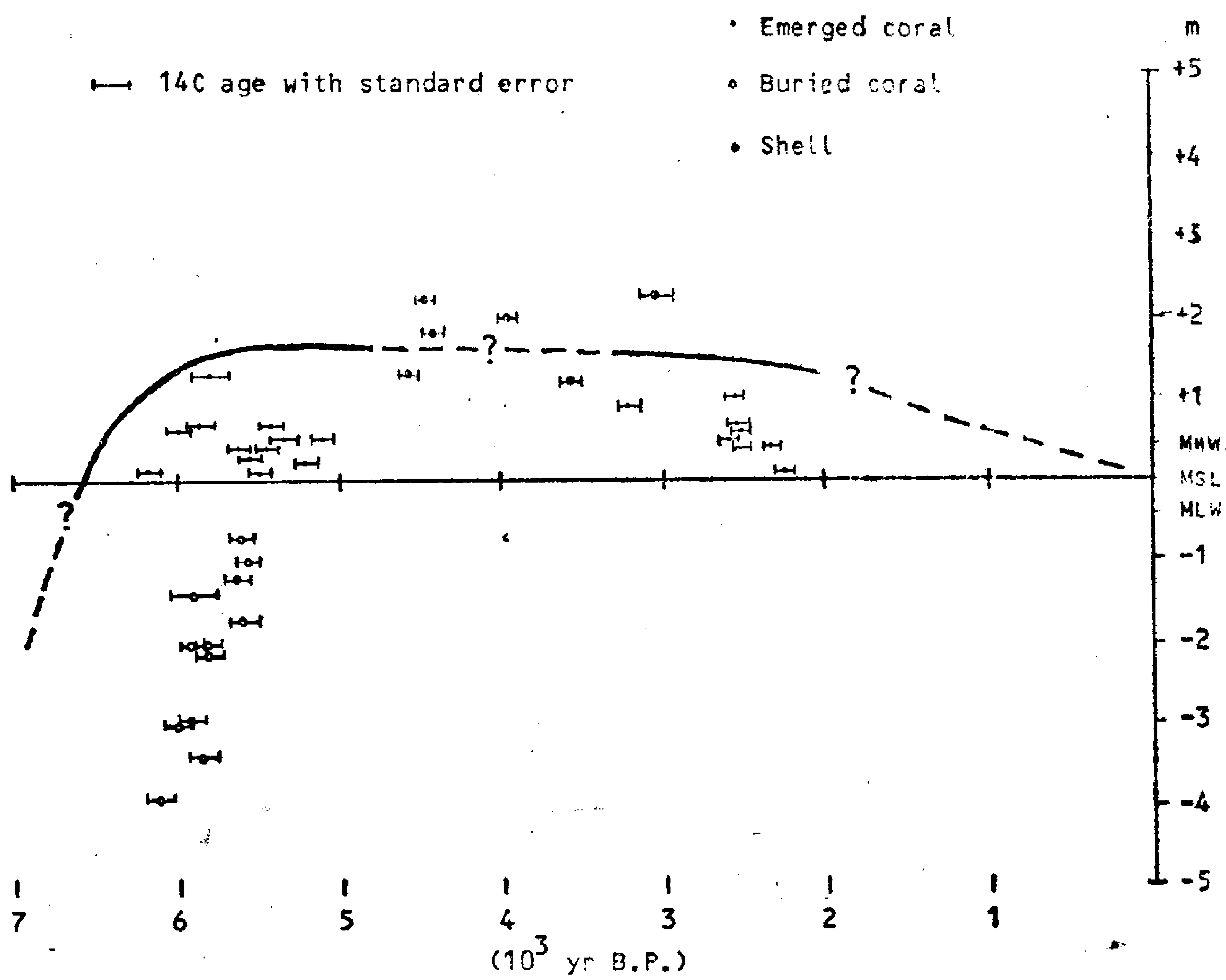

Fig. 6. Mid and Late Holocene sea level change in Sri Lanka (Katupotha and Fujiwara, 1988).

TABLE I

Time Ranges and Events of Late Quaternary in Sri Lanka

yr. B.P.	Blytt-Sernander Classification (B)	Mid-latitude Mean Temperature Departures (B) (°C)	Eustatic Phases and Elevation (B) (metre)	Climate	Sri Lanka Event/Formation
0/1000	**Late Subatlantic** -600 B.P.	+1°	E (-2)	Cold Phase	Estuarine deposits ; Fore-dune deposits (Northwest and southeast coast)
	(Present Climate) -1000 B.P.	+0.5°	S (30-60 cm)	Warm Phase	Estuarine deposits ; Coastal swamps (west and south coasts)
1000 -2300	**Early Subatlantic** -1600 B.P.	+1°	S (60 cm)	Warm Phase	Estuarine deposits ; Coastal swamps (West and south coasts)
	-2000 B.P.	+0.5°	E (-2)	Cold Phase	Estuarine deposits (Inland buried shell deposits - Chilaw) ; Beach ridges ; Dune deposits (C)
	-2300 B.P.	+1°	S (1.5-2m)	Warm Phase	Estuarine Marine deposits (Emerged fossil corals (South coast) ; Coastal swamp deposits) ; Submerged the west coast by a tsunami? (D)

Table 1 (Continued)

2300 -3700	**Late Subboreal** -3000 B.P.	+1·	E (-3)	Cold Phase	Estuarine deposits ; Emerged coral deposits (South coast) ; Emerged beachrock (West and south coast) ; Beachridges ; Dune deposits (C)
3700 -5300	**Early Subboreal** -4000 B.P.	+2·	S (-3)	Warm Phase	Estuarine deposits (Inland buried coral deposits (South coast) ; Coastal swamp deposits) ; Higher sea level (C)
	–4300 B.P.	+0.5·	E (-4)	Cold Phase	Estuarine deposits (Inland fossil shells-south coast) ; Emerged beachrock ; Beach ridges ; Dune deposits (Southeast coast); Lower sea level (CF)
5300 -6600	**Main Atlantic** -5500 B.P.	+2.5·	S (3-5)	Warm Phase	Estuarine/Marine deposits (Inland buried coral deposits and emerged corals ; Coastal swamp deposits ; P1.5 m higher sea level than at present MSL (E)
	–6500 B.P.	+1·	E (-10)	Cold Phase	Rising of sea-level ; Submergence of near-shore forests ; Beachrock of western continental shelf (about 10m below from present MSL)
6600 -7500	**Early Atlantic** -7000 B.P.	+2·	S	Warm Phase	Rising of sea-level
7500 -8700	**Late Boreal** -7500 B.P.	+0.5·	E	Cold Phase	Rising of sea -level ; Beachrock of western continental shelf
	-7800 B.P.	+1·	S	Warm Phase	Rising of sea-level

8700 P9800	**Early Boreal** -8800 B.P.	+0.5°	E	Cold Phase	Rising of sea-level ; Beachrock of western continental shelf (about 18m below from present MSL
9800 -10,300	**Preboreal**	+1°	S (-) 15-24	Warm Phase	Rising of sea-level ; Beachrock of western continental shelf (about 25m below from present MSL)
10,300 -10,900	**Younger Dryas**	+3°	E	Arid Phase	
10,900 -11,800	**Allerod**	+2°	E (-) 32-40	Arid Phase	Red Beds (Iranamadu Formation A)
11,800 -15,000	**Older Dryas**	7°	S (-) 45-60		Palugahaturai **Arid** Phase ; Red Beds and Bundala dunes ; (A)
17,000 -30,000	**Main Würm**		E (-) 80-100		Palugahaturai **Arid** Phase ; Red Beds ; Bundala dunes and Bellanbendi deposits (A)
30,000 -60,000					Ratnapura Climatic Phase III

S = Submergence, E = Emergence, **Subatlantic** = About 3,200 B.P. in post-glacial, **Subboreal** = About 5,200 B.P. in post-glacial, **Atlantic** = Between 5,200 and 7,500 B.P. in post-glacial, **Boreal** = 7,500 B.P. to 9,500 (early period of the post-glacial), **Preboreal** = The first phase of the post-glacial climatic period, **Younger Dryas** = The end of the Late-Glacial and the beginning of the post-glacial, **Allerod** = Zone II in the Late-Glacial period, **Older Dryas** = One of the five phases of the Late-Glacial, **Würm** = The last glacial stage of the Pleistocene period.

Source : (A) — Deraniyagala (1976 and 1986) ; (B) = Fairbridge (1968 and 1982) ; (C) = Katupotha (1988a, 1988b) ; (D) = Katupotha, 1991 ; (E) = Katupotha and Fujiwara (1988) ; (F) = Katupotha and Wijayananda (1989).