

HOLOCENE SEA LEVEL CHANGE ON THE SOUTHWEST AND SOUTH COASTS OF SRI LANKA

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Abstract

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¹⁴C dates of coral and shell samples from Sri Lanka produce the following results. Nineteen samples from emerged coral reef patches on small headlands show two different age groups related to high sea levels: 6170 ± 70 – 5100 ± 70 yr B.P. and 3210 ± 70 – 2330 ± 60 yr B.P. respectively. Buried coral deposits from the present backmarsh also indicate an age of 6110 ± 80 – 5560 ± 70 yr B.P. This substantiates the fact that these corals have thrived in bays or lagoons as a result of the marine transgression in the mid-Holocene. Comparing ages and heights of the samples with the mean low water spring level, which is the highest level of present living corals, it is concluded that the mean sea levels between 6170 ± 70 – 5100 ± 70 yr B.P. and 3210 ± 70 – 2330 ± 60 yr B.P. were at least 1.0 m higher than the present mean sea level.

Introduction

Many field-workers are applying various types of dating methods, microfossil and pollen analyses, etc. to the study of Holocene sea level changes. The island of Sri Lanka, situated on the Australian–Indian Plate (Ollier, 1981), is subjected to drowned former coasts during the final phase of the Würm glaciation (Swan, 1967), and evidence of recent oscillatory movements of sea levels which can be seen along the coasts and lower drainage basins (Coates, 1935; Deraniyagala, 1958). Hence Sri Lanka is important for examination of sea-level changes in the Holocene Epoch.

No age dating facilities are available in Sri Lanka and it is difficult to consider such sea levels using the very few published dates (Hubbs et al., 1962; Stoddart and Pillai, 1972;

Neef and Veeh, 1981). The present study has focused on the preliminary dating of fossil corals and shells collected on the southwest and south coasts (Fig.1) during August 1985 and November 1986 to determine Holocene sea levels.

Materials and method

Coral and shell samples were treated with 10% HCl, and pure CaCO₃ samples were dated by liquid scintillation counting of methanol, at the Department of Geography, Hiroshima University radiocarbon dating laboratory, using the laboratory procedure described by Fujiwara and Nakata (1984). The results are expressed in radiocarbon years relative to 1950 AD based on the Libby half-life of 5568 ± 30 years, using the new NSB oxalic acid standard (SRM 4900C) as "modern" (Stuiver, 1983). The landform maps of the area were compiled by aerial photograph interpretation (1:40,000 — Survey Department of Sri Lanka, 1956).

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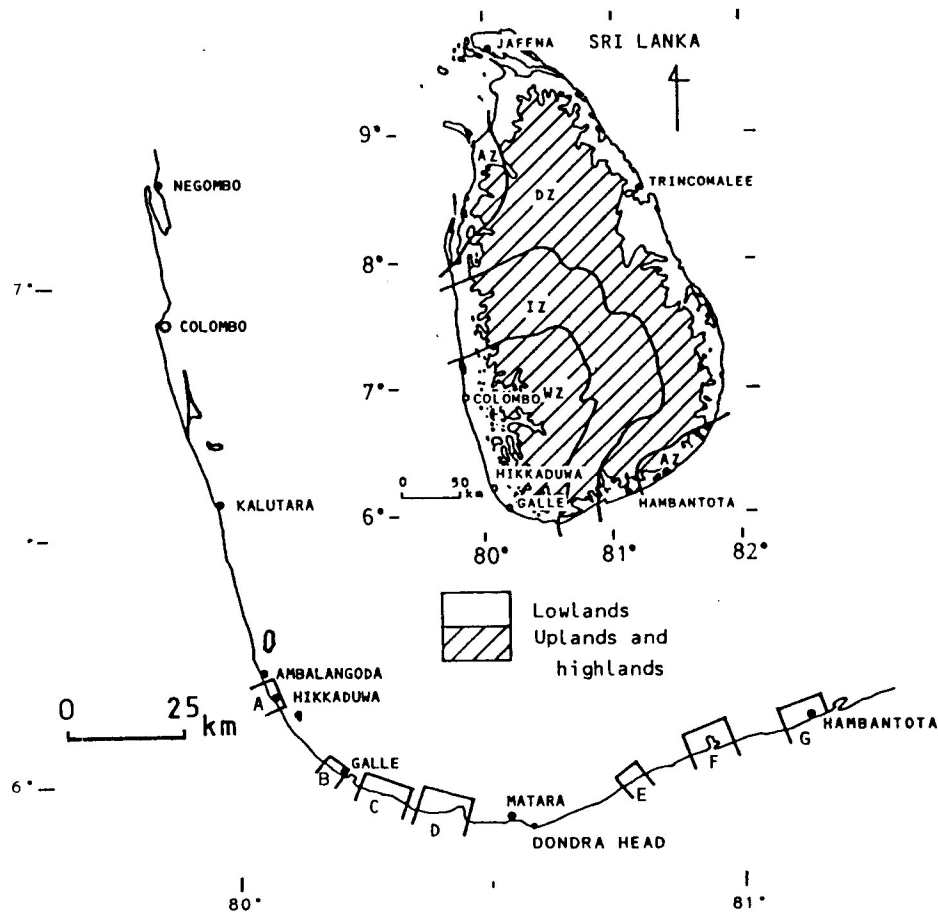


Fig.1. Sketch map showing the location and the distribution of sampled area on the southwest and south coasts. AZ=Arid Zone; DZ=Dry Zone; IZ=Intermediate Zone; WZ=Wet Zone. A: Akurala, Akurala-Telwatte and Hikkaduwa. B: Dadalla. C: Mihiripenna, Habaraduwa and Koggala. D: Aranwala, Denuwala and Palalla. E: Pallikkudawa. F: Hungama and Kalametiya. G: Karagan Lewaya and Udamalala.

Survey area

Sri Lanka has a coastline over 1920 km in length, exhibiting a diversity of coastal landforms (with elevation from MSL to 30 m) consisting of beaches, sand bars, spits, lakes and lagoons with marshy belts and mangrove swamps which overlie weathered crystalline rocks of the Precambrian age or Miocene limestone deposits.

Coastal landforms of Sri Lanka have a close relationship with major climatic zones. Northern and eastern coastal lowlands, which correlate with "Intermediate", "Dry" and "Arid" Zones, are formed of sand bars and

barrier beaches with lagoons. Along the "Wet" southwest and south coasts, bedrock related residual hills and ridges approach nearest to the sea (Figs.1 and 2). The tidal range on Sri Lanka coasts is small, ranging from the mean low water spring (MLWS) at -0.37 m and mean high water spring (MHWS) at $+0.4$ m from mean sea level (MSL-data based on Colombo datum: 0.38 m below MSL; Tide Tables, vol.2, Pacific and Indian Oceans, 1982). However, high waves (height 5.0 m or over) are seen along the southwest and south coasts and are related to the strong southwest monsoon from May to September.

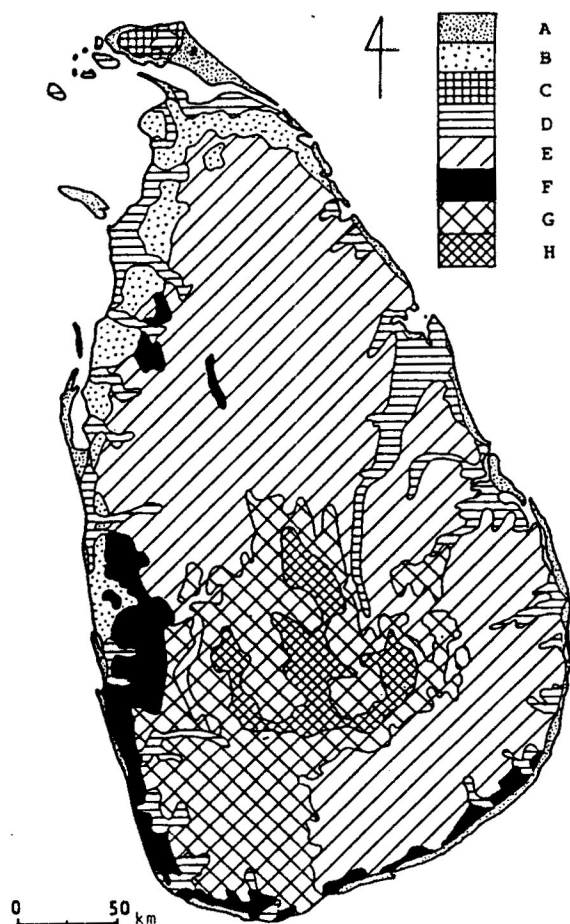


Fig.2. Simplified landforms map of Sri Lanka (after Swan 1982). A=Holocene beaches and sand dune. B=Old beaches. C=Limestone lowlying platforms. D=Fluvial, deltaic and marshy lands, and associated water bodies. E=Undulating terrains. F=Low hills, ridges and terraces. G=Steep scarps, ridges and associated plateaus. H=High plateaus and plains.

Many areas along the southwest and south coasts include living corals, emerged reef patches, well developed buried coral and shell deposits, and beachrock shoals. The present living corals in front of the southwest coast thrive from MLWS to 4 m in depth in lagoon reef areas and to 8 m in fringing reef areas. Extensive buried coral deposits occur between Ambalangoda and Matara, and stretch from 250 m to several kilometers inland from the present shore. These deposits are largely exploited for lime burning in many places. The

emerged coral reef patches are at or above MHWS, and scattered at the points of small headlands.

On the south coast, extensive wetlands (marshes, mangrove swamps etc.) extend many kilometers inland from the present shore. Two types of marine deposits at Palalla, to the north of Weligama Bay, are composed of varieties of shell and coral debris, and mixed with quartz pebbles and fine to coarse sand, and black to greenish-gray lagoon mud. These deposits are presently covered by wind blown sand.

Buried coral deposits are not well developed in the area to the east of Dondra Head on the south coast. These areas are located in the Intermediate and Dry Zones of the study location. The lagoons in the area are formed of irregular basins bounded on the land side by bluffs of decomposed rock. Beach bars are capped by wind blown sand (Coates, 1935), and other lowlands occupied by marshes and wastelands. The extensive shell bearing clay beds are found along the rims of lagoons, and the height of the deposits vary between 3.0 and 5.0 m above MSL. On the south coast, these shell deposits are being exploited for lime burning, chemicals and chicken grit.

Some shell deposits found around the Hambantota lagoon complex on the south coast mainly in the Kalametiya and Udamalala areas. These deposits are held together with reddish-yellow sand and pale-yellow sand in layers several centimeters in thickness.

Results

Southwest coast

The age sequences of nine samples collected from buried coral deposits at Akurala are shown in Figs.3 and 4. The upper layers of these coral deposits are covered by calcareous sandy clay with coral debris. The upright corals consist of various species of branching (*Acropora*) and massive (*Porites*, *Favites* and *Goniopora*) corals, and are in a position of growth. The layers vary from 4.0 to 5.0 m in

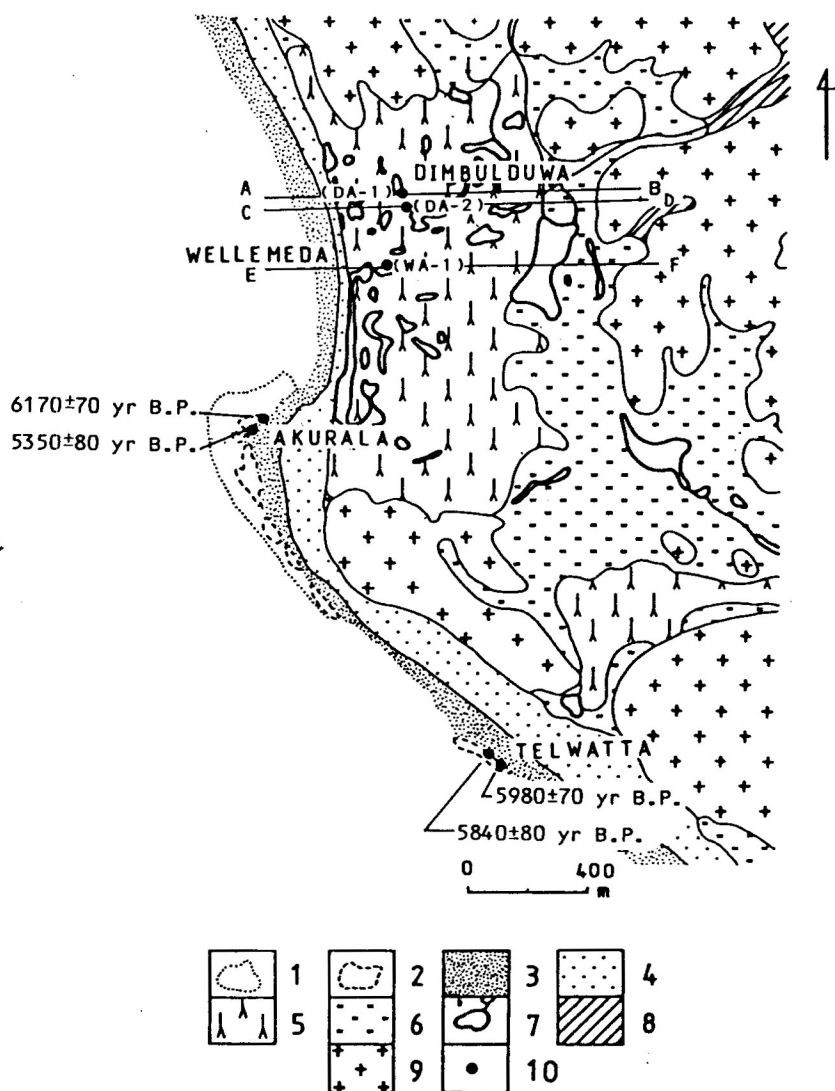


Fig.3. Landforms map showing buried and emerged coral deposits at Akurala and Akurala-Telwatta. Cross-sections are referred to in Fig.4. 1=Inter-tidal reef patch. 2=Emerged reef patch. 3=Foreshore. 4=Beach ridge. 5=Mangrove swamp. 6=Marsh. 7=Water hole, lake and stream. 8=Flood or valley plain. 9=Residual hill and ridge. 10=Sample location.

thickness and they are laid on a sand and mud layer. Such deposits suggest a fluvial or brackish swampy environment during their deposition. Undamaged shells, which were deposited with corals, show that they were not accumulated by wave action. The samples of the lowest and uppermost parts of the deposits have been dated at 6110 ± 80 yr B.P. (HR-109) and 5590 ± 80 yr B.P. (HR-236) respectively, and their height varies between 1.4 and 3.9 m below

MSL (Fig.4). These sequences reveal that the corals thrived in a bay or lagoon in the mid-Holocene.

Emerged coral reef patches at Akurala and Akurala-Telwatta (Fig.3) consist of various species of coral (Table I). Five coral samples were collected at levels between 0.1 and 0.7 m above MSL and their ages vary from 6170 ± 70 yr B.P. to 5350 ± 80 yr B.P. (Fig.3 and Table I). ^{14}C dates from emerged coral reef patches at

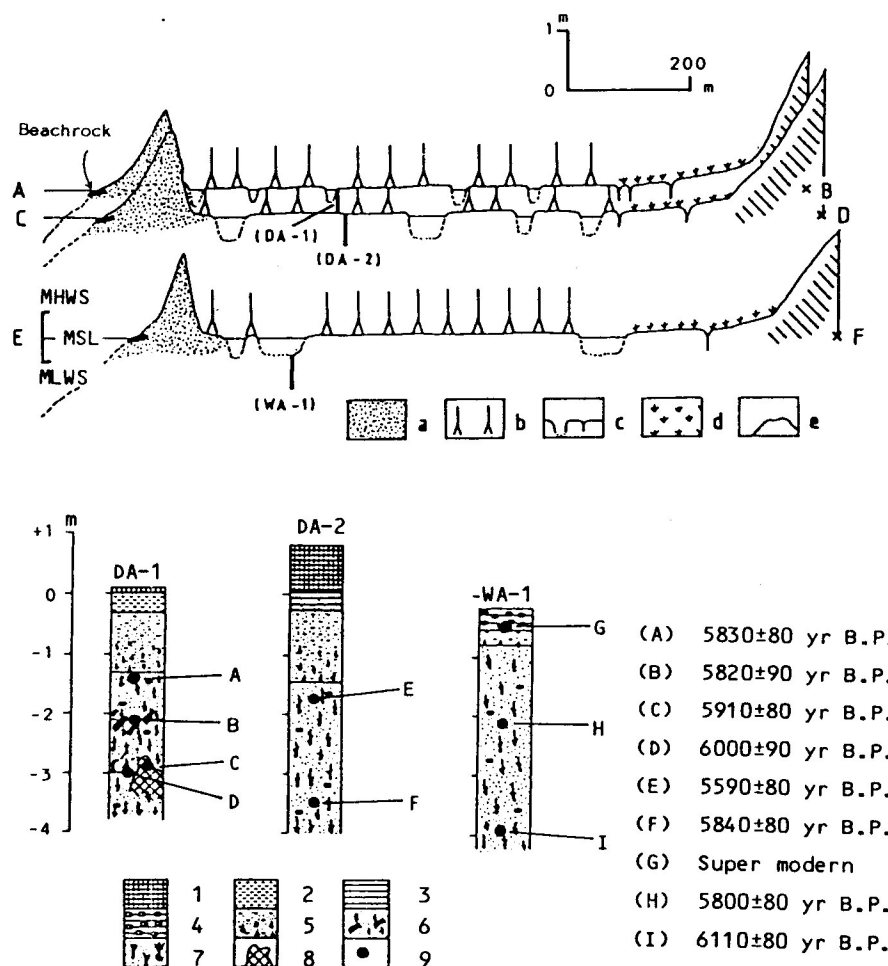


Fig.4. Cross-sections, stratigraphic and radiocarbon age datings of three coral quarries at Akurala. ^{14}C dates are referred to in Table I. DA-1=Dimbulduwa-Akurala; DA-2=Dimbulduwa-Akurala; WA-1=Wellemeda-Akurala. q =Beach ridge. b =Mangrove swamp. c =Water hole, lake and stream. d =Marsh. e =Residual hill and ridge. l =Top soil. 2=Brownish gray soil. 3=Dark gray mud. 4=Dark olive gray mud with shell. 5=Calcareous sandy clay with coral fragment. 6=Stratified coral (*Acropora* and *Echinopora*). 7=Stratified coral *Acropora*. 8=Massive coral. 9=Sample location.

Hikkaduwa (Fig.5) show two different age groups. One sample dated at 5100 ± 70 yr B.P. (HR-116, at 0.5 m above MSL). This correlates with the emerged coral reef patches at Akurala and Akurala-Telwatte. But the other two samples indicate separate ages: 3210 ± 70 yr B.P. (HR-242) and 2560 ± 60 yr B.P. (HR-243, Table I). Two samples collected from emerged reef patches at Dadalla (Fig.1) show 5200 ± 70 yr B.P. (HR-244, at 0.2 m above MSL) and 5480 ± 70 yr B.P. (HR-245, at 0.1 m above MSL) and they are correlated to the first age group mentioned above. These ages and heights of

emerged coral samples indicate that sea level was above the present MSL since 6170 ± 70 yr B.P.

Five ^{14}C dates of coral and shells from exposed coral quarries at Mihiripenna (Fig.6) and Habaraduwa (Fig.1) give ages from 5970 ± 70 yr B.P. to 5600 ± 70 yr B.P. (Table I). The height of the samples varies between 0.7 and 2.0 m below MSL. The age sequences indicate that the coral thrived in a bay or a lagoon in the mid-Holocene. The stratigraphic sequence of these coral deposits is quite similar to the deposits at Akurala.

TABLE I

Dated coral and shell samples on the southwest and south coasts of Sri Lanka

No.	Locality	Altitude* (m)	Dated material	Age (1/2 life = 5568 ± 30) (yr B.P.)	Laboratory no.
SOUTHWEST COAST					
Dimbulduwa-Akurala					
	(Coral quarry)				
1	6°12'10"N 80°03'57"	-1.4	<i>Acropora</i>	5830 ± 90	HR 111
2	6°12'10"N 80°03'57"	-2.0	<i>Echinopora</i>	5820 ± 90	HR 112
3	6°12'10"N 80°03'57"	-2.9	<i>Porites</i>	5910 ± 80	HR 113
4	6°12'10"N 80°03'57"	-3.0	<i>Acropora</i>	6000 ± 90	HR 114
	(Coral quarry)				
5	to the southeast No. 1	-1.7	<i>Acropora</i>	5590 ± 80	HR 236
6	to the southeast No. 1	-3.4	<i>Acropora</i>	5840 ± 80	HR 237
Wellemeda-Akurala					
	(Coral quarry)				
7	6°11'50"N 80°03'57"E	-0.3	Thiaridae	recent	HR 115a
8	6°11'50"N 80°03'57"E	-2.1	<i>Acropora</i>	5800 ± 80	HR 115b
9	6°11'50"N 80°03'57"E	-3.9	<i>Acropora</i>	6110 ± 80	HR 109
Akurala					
	(Emerged coral)				
10	6°10'30"N 80°03'35"E	+0.5	<i>Acropora</i>	5350 ± 80	HR 238
11	Near to No. 10	+0.1	<i>Platygyra</i>	6170 ± 70	HR 239
Akurala-Telwatta					
	(Emerged coral)				
12	6°10'10"N 80°03'50"E	+0.6	<i>Acropora</i>	5840 ± 80	HR 240
13	to the south of No. 12	+0.6	<i>Montipora</i>	5980 ± 70	HR 241
Hikkaduwa					
	(Emerged coral)				
14	6°07'45"N 80°05'45"E	+0.5	<i>Goniastrea</i>	5100 ± 70	HR 116
15	40 m north of No. 15	+1.0	<i>Goniastrea</i>	3210 ± 70	HR 242
16	60 m east of No. 15	+1.0	<i>Goniastrea</i>	2560 ± 60	HR 243
Dadalla					
	(Emerged coral)				
17	6°02'25"N 80°11'30"E	+0.2	<i>Platygyra</i>	5200 ± 70	HR 244
18	Near to No. 17	+0.1	<i>Goniopora</i>	5480 ± 70	HR 245
Mihiripenna					
	(Coral quarry)				
19	6°00'20"N 80°15'50"E	-0.7	<i>Acropora</i>	5600 ± 70	HR 246
20	6°00'20"N 80°15'50"E	-1.2	Tridacnidae	5630 ± 70	HR 247
21	6°00'20"N 80°15'50"E	-1.4	<i>Porites</i>	5970 ± 70	HR 248
22	6°00'20"N 80°15'50"E	-2.0	<i>Acropora</i>	5910 ± 70	HR 249
Habaraduwa					
	(Coral quarry)				
23	5°59'50"N 80°17'00"E	-0.9 ~ -1.1	<i>Acropora</i>	5560 ± 70	HR 110
SOUTH COAST					
Koggala					
	(Emerged coral)				
24	5°59'00"N 80°19'25"E	+0.4	<i>Goniopora</i>	5440 ± 70	HR 250

TABLE I (continued)

No.	Locality	Altitude* (m)	Dated material	Age (1/2 life = 5568 ± 30) (yr B.P.)	Laboratory no.
Aranwala (Emerged coral)					
25	5°58'00"N 80°22'30"E	+0.4	<i>Goniastrea</i>	2330 ± 60	HR 251
26	to the east of No. 25	+0.3	<i>Goniopora</i>	5540 ± 70	HR 252
27	to the east of No. 26	+0.1	<i>Goniastrea</i>	2250 ± 60	HR 253
Denuwala (Emerged coral)					
28	5°57'55"N 80°23'10"E	+0.7	<i>Acropora</i>	2540 ± 60	HR 254
29	to the east of No. 28	+0.5	<i>Galaxea</i>	2580 ± 60	HR 255
30	to the east of No. 29	+0.6	<i>Acropora</i>	2510 ± 60	HR 256
31	to the east of No. 30	+0.4	<i>Favites</i>	2520 ± 60	HR 257
Palalla-Weligama (Shell deposit)					
32	5°59'50"N 80°25'55"E	+1.8	Veneridae	4420 ± 70	HR 258
33	To the west of No. 32	+1.3	Veneridae	4560 ± 60	HR 259
Pallikkudawa (Emerged coral)					
34	6°01'00"N 80°47'30"E	+0.4	<i>Goniastrea</i>	5610 ± 70	HR 269
35	Near to No. 34	+0.7	<i>Platygyra</i>	5470 ± 70	HR 270
Hungama (Shell deposit)					
36	6°06'30"N 80°55'30"E	+1.3	Veneridae	5780 ± 110	HR 124
Kalametiya (Shell deposit)					
37	6°05'08"N 80°56'45"E	+1.2	Veneridae	3570 ± 60	HR 265
Kalametiya (Shell deposit)					
38	6°05'15"N 80°57'08"E	+2.2	Veneridae	4460 ± 60	HR 266
Kalametiya (Shell deposit)					
39	6°06'10"N 80°57'15"E	+2.0	Veneridae	3960 ± 60	HR 267
Karagan Lewaya (Shell midden)					
40	6°07'20"N 80°05'10"E	+2.3	Veneridae	3050 ± 100	HR 123
Udamalala (Shell midden)					
41	6°10'15"N 88°10'00"E	+6.5 (Approx.)	Veneridae	4050 ± 60	HR 122
42	to the north of No. 41	+5.0 (Approx.)	Veneridae	4650 ± 70	HR 268

*Above the present MSL.

South coast

Along the south coast, emerged and buried coral deposits and shell deposits were found at various levels. A sample from an emerged reef patch at Koggla (Fig.1) was dated at 5440 ± 70

yr B.P. (HR-250, at 0.4 m above MSL). The age and height are related to the first age group on the southwest coast.

Seven coral samples were collected at various levels of emerged reef patches at Aranwala and Denuwala (Fig.1 and Table I). The ages of

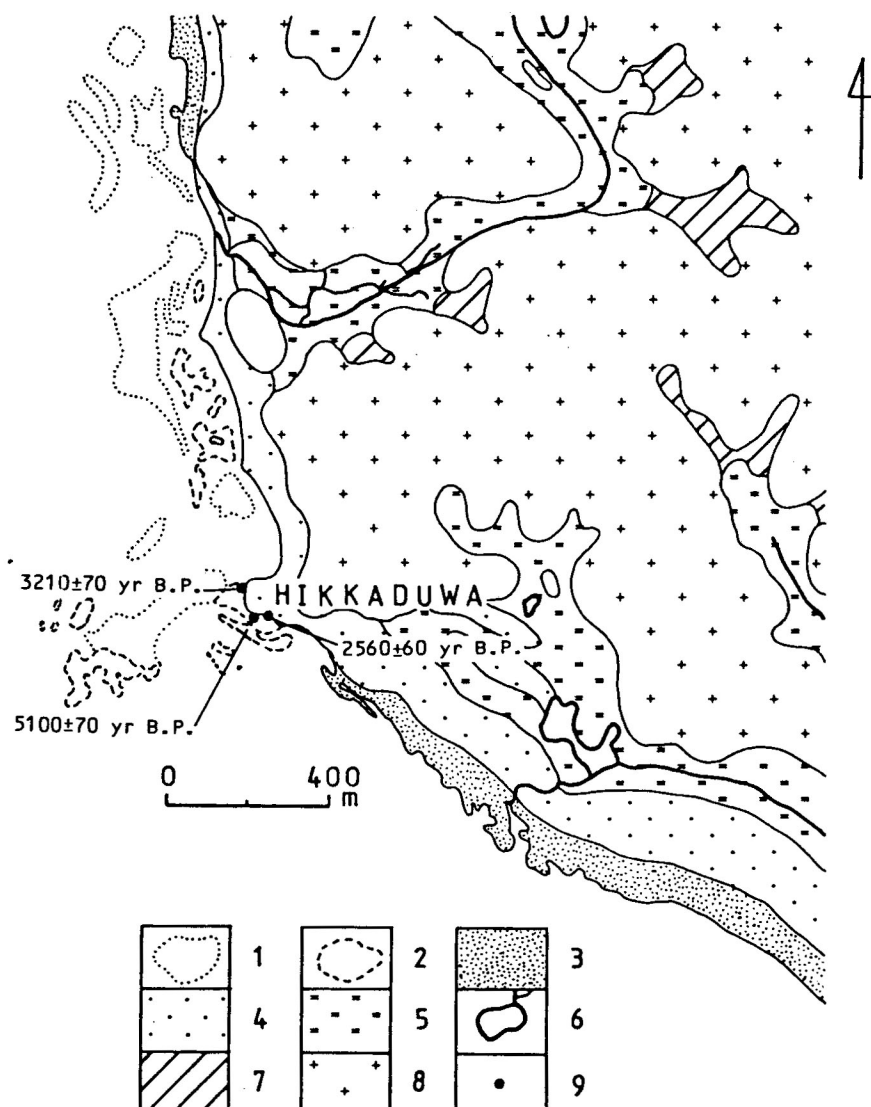


Fig.5. Landform map of the Hikkaduwa area. ^{14}C dates of emerged coral reef patches are referred to in Table I. 1=Inter-tidal reef patch. 2=Emerged reef patch. 3=Foreshore. 4=Beach ridge. 5=Marsh. 6=Water hole, lake and stream. 7=Flood or valley plain. 8=Residual hill and ridge. 9=Sample location.

these samples also can be divided into two groups. One sample at Aranwala was dated at 5540 ± 70 yr B.P. (HR-252, at 0.3 m above MSL). Other ages range from around 2580 ± 60 to 2330 ± 60 yr B.P. with heights from about 0.1 to 0.7 m above MSL (Table I). The two ages and levels correspond very clearly with the age groups at Akurala, Akurala-Telwatta and Hikkaduwa.

Two shell samples from separate cores (col-

lected by a hand auger) at Palalla (Fig.7) were dated at 4420 ± 70 yr B.P. (HR-258, at 1.8 m above MSL) and 4560 ± 60 yr B.P. (HR-259, at 1.3 m above MSL). The first sample was composed of varieties of shell fragments of Veneridae, Cypræidae, Pyramidæ, Turbinidae, Mytilidae, Trochidae, Articiidae, Cardiidae etc. and of coral debris showing that they were accumulated in backshore beaches by wave action. The shells with bivalves of the second sample,

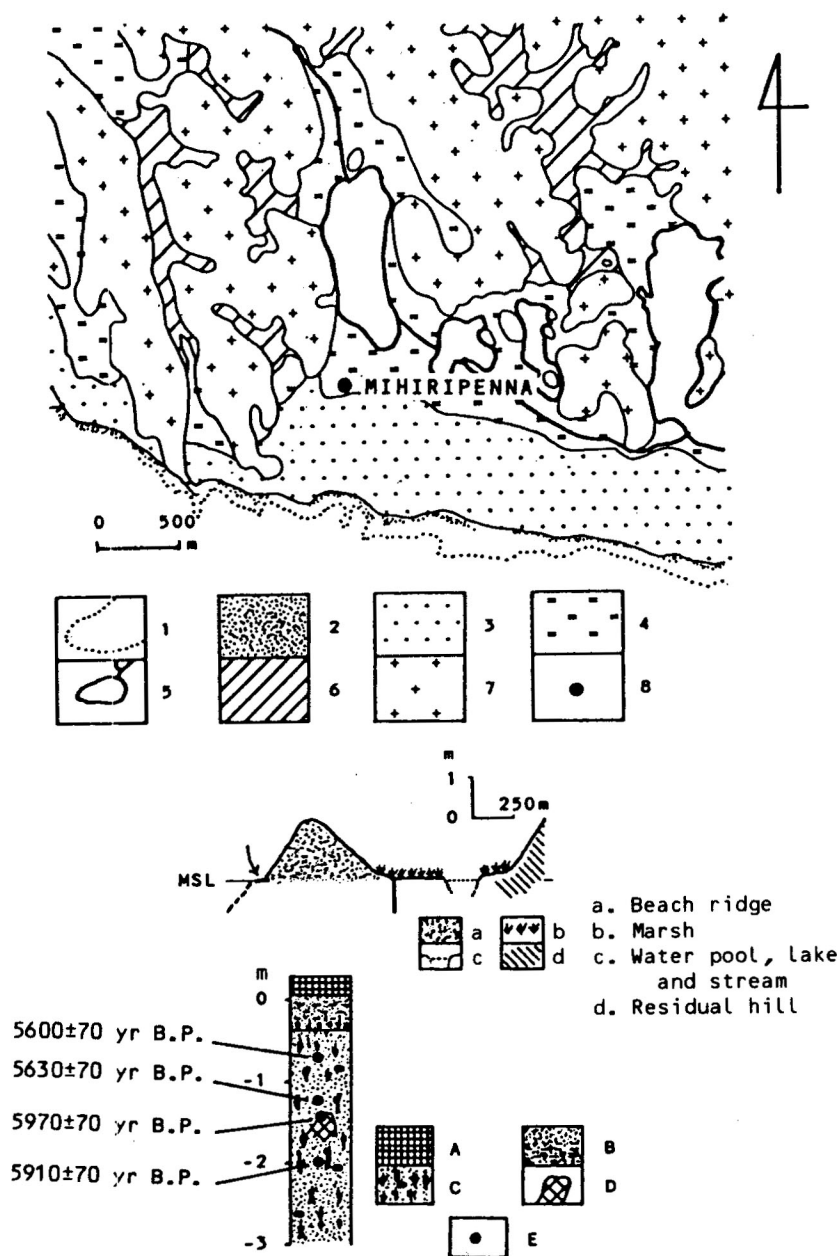


Fig.6. Map showing landforms of the Mihiripenna area. ^{14}C dates of samples from a coral quarry are referred to in Table I. 1= Inter-tidal reef patch. 2= Foreshore. 3= Beach ridge. 4= Marsh. 5= Water hole, lake and stream. 6= Flood or valley plain. 7= Residual hill and ridge. 8= Sample location. A= Top soil, B= Light gray soil, calcareous sandy clay with coral fragments. C= Stratified coral (*Acropora*). D= Massive coral. E= Sample location.

collected from the black to greenish lagoon mud (at distance about 30 m westwards from core 1), are assumed to be in situ.

At Pallikkudawa (Fig.1) two samples from the emerged reef patches were dated at

5610 ± 70 (HR-269) and 5470 ± 70 yr B.P. (HR-270), and heights were at 0.4 m and 0.7 m above MSL respectively. The ages and levels almost coincide with the first age group of the southwest coast.

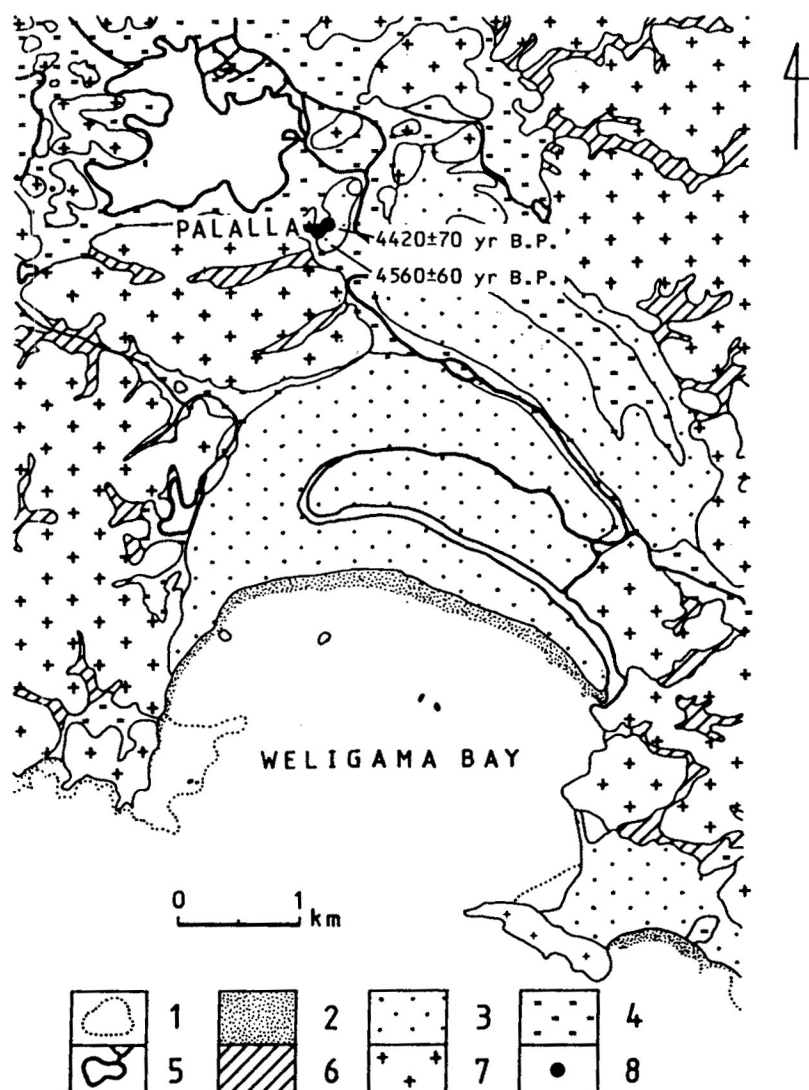


Fig.7. Map showing landforms around Weligama Bay. ^{14}C dates of shells from two cores are referred to in Table I. 1= Inter-tidal reef patch. 2= Foreshore. 3= Beach ridge. 4= Marsh. 5= Water hole, lake and stream. 6= Flood or valley plain. 7= Residual hill and ridge. 8= Sample location.

^{14}C dates of five shell samples collected from along the rim of Kalametiya Kalapuwa (lagoon, Fig.8) are included into lagoonal deposits which are composed of calcareous clay, black to blue-black mud and clay. One sample of these dated at 5780 ± 120 yr B.P. (HR-124, at 1.3 m above MSL). The other ages range from 4460 ± 60 to 3570 ± 60 yr B.P., and heights were between at 0.8 m and 2.2 m above MSL (Table I).

The heights and the matrix of the shell deposits at Karagan Lewaya and Udamalala

show morphological differences from other shell deposits (Figs.9 and 10). Considering the heights and composition of these deposits, they can be identified as shell middens, and the ages of these deposits vary between 4650 ± 70 yr B.P. and 3050 ± 100 yr B.P. (Table I).

Discussion

Emerged reefs provide the best evidence for sea-level changes (Hopley, 1986). A sea-level

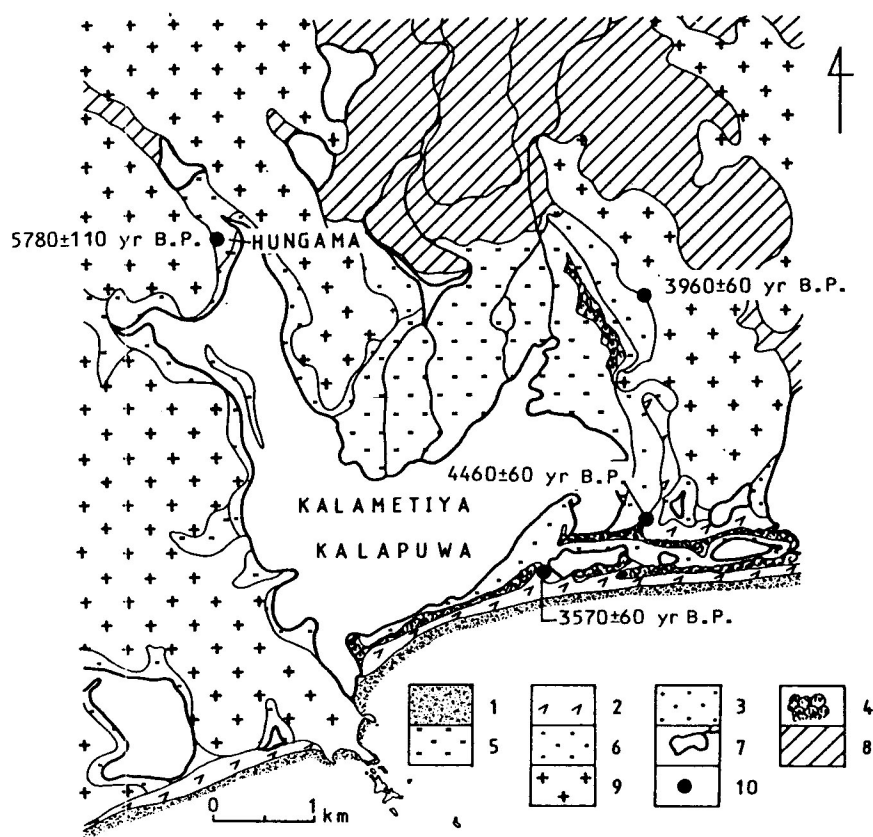


Fig.8. Map showing landforms around Kalametiya Kalapuwa (lake). ^{14}C dates of shell deposits are referred to in Table I. 1=Inter-tidal reef patch. 2= Foreshore. 3= Sand dune. 4= Beach ridge. 5= Marsh. 6= Wasteland. 7= Water hole, lake and stream. 8= Flood or valley plain. 9= Residual hill and ridge. 10= Sample location.

curve in the Holocene Epoch in Sri Lanka can be produced by comparing the ages of samples from emerged reef patches, buried corals, and heights of the samples with the present tidal range (Fig.11). As shown in Fig.11 and Table I, nineteen ^{14}C dates of emerged coral samples (in a position of growth) collected from reef patches of small headlands can be divided into two age groups. The first age group ranges between 6170 ± 70 and 5100 ± 70 yr B.P. and the other ranges between 3210 ± 70 and 2330 ± 60 yr B.P. The levels of the two groups are similar in height and cannot be distinguished easily in the field. Comparing the present MLWS level, which is the highest level of present living corals, and these two age groups, it is assumed that between 6170 ± 70 and 5100 ± 70 yr B.P. MSL was at least 1.0 m above the present MSL.

The lack of emerged coral datings between the two age groups suggests a temporary death of the coral reef, and it is supposed that a lowering of sea level has occurred after 5100 ± 70 yr B.P., and that once again sea level elevated between 3210 ± 70 and 2330 ± 60 yr B.P. However, considering the ^{14}C dates of shell deposits which are accumulated on the backshore beaches, it is also supposed that the MSL was not lowered between these two age groups.

^{14}C dates of buried coral deposits vary from 6100 ± 80 yr B.P. to 5560 ± 70 yr B.P., and it can be shown that they had thrived in bays or lagoons. This was a result of a marine transgression in the mid-Holocene. A lack of both sand and freshwater supplies from rivers to bays or lagoons produces favourable condi-

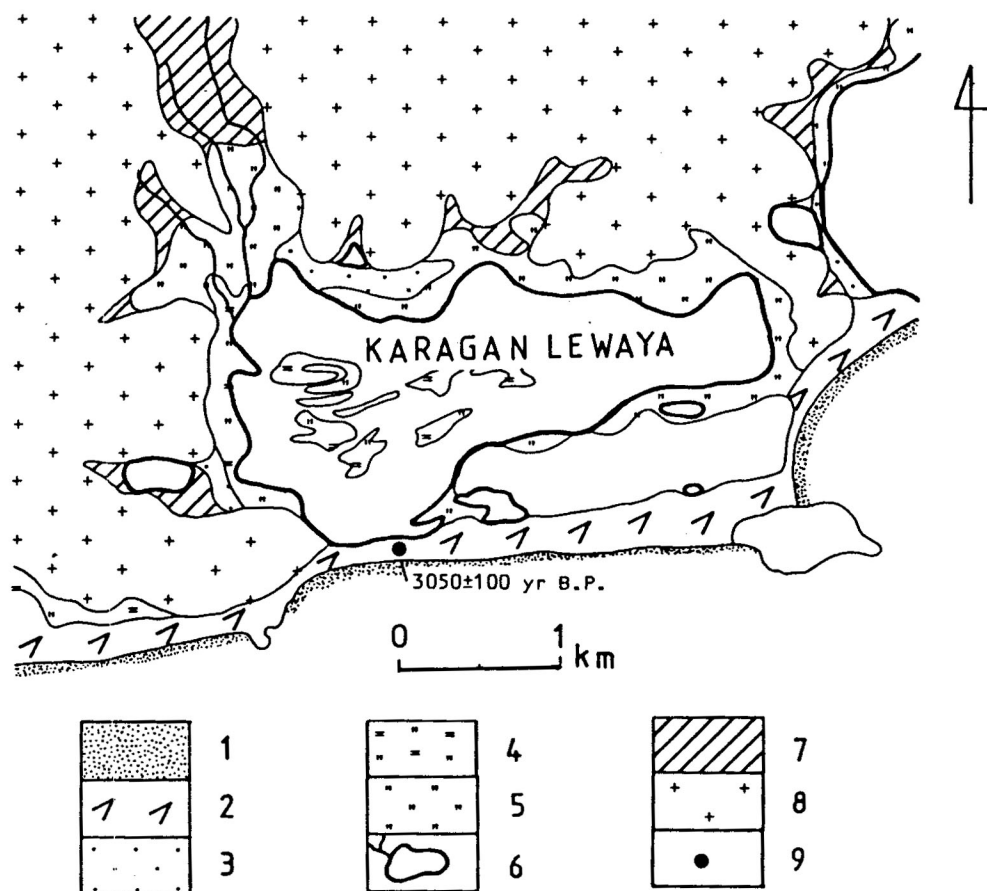


Fig.9. Landforms map around Karagan Lewaya (lake). ^{14}C date of a sample from a shell midden is referred to in Table I. 1= Foreshore. 2= Sand dune. 3= Beachridge. 4= Marsh and wasteland. 5= Wasteland. 6= Water hole, lake and stream. 7= Flood or valley plain. 8= Residual hill and ridge. 9= Sample location.

tions for the growth of corals. At present similar environmental conditions appear along the southwest coast, mainly at the Hikkaduwa area. Mergner and Scheer (1974) divided the lagoon reef in front of Hikkaduwa into four zones (from inland to sea): shore, reef lagoon with inner reef patches, outer barrier and littoral flat. The composition of buried coral deposits of the palaeo-lagoon at Akurala is very similar to that of the present reef lagoon zone, with inner reef patches which occur from MLWS level to 4 m in depth. In comparing these levels with the lowest and upper levels of thirteen dated samples from buried coral deposits of the palaeo-lagoon, it is estimated that the MSL was higher than at present by at least

0.5 m at 6110 ± 80 yr B.P. and at least 1.0 m or more at 5560 ± 70 yr B.P., respectively. These high sea levels are most similar to those of the first age group of emerged corals.

According to the geological structure, the rivers of the south coast supply more fluvial materials and fresh water into bays or lagoons than the rivers of the southwest coast. Such environmental conditions were not suitable for coral growth, especially on the east of Dondra Head, although these features favoured marine shells. One Veneridae fossil shell sample collected from the Ruchigal Oya (river) mouth, north of Kalametiya Kalapuwa, dated at 5780 ± 110 yr B.P. (HR-124, at 1.3 m above MSL). This date indicates that the shells lived

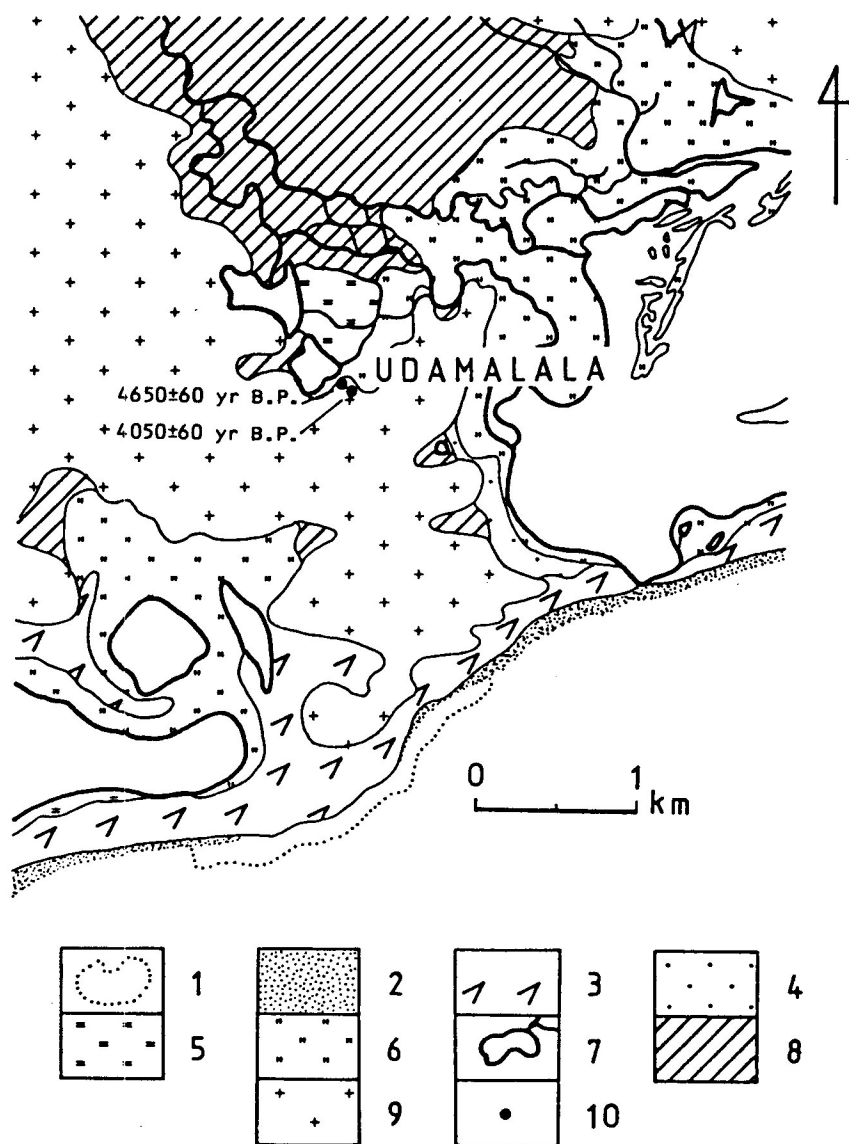


Fig.10. Landform map of the Udamalala area. ^{14}C dates of samples from two shell middens are referred to in Table I. 1 = Inter-tidal reef patch. 2 = Foreshore. 3 = Sand dune. 4 = Beachridge. 5 = Marsh. 6 = Wasteland. 7 = Water hole, lake and stream. 8 = Flood or valley plain. 9 = Residual hill and ridge. 10 = Sample location.

in a brackish water environment, and it is assumed that they extended perhaps about 3 or 4 km inland from the shore (Figs.7 and 8) between 6170 ± 70 and 5100 ± 70 yr B.P. The composition of other shell samples around Kalametiya Kalapuwa indicates that the shells were accumulated by high wave action on the rims of former lagoon or backshore beaches, possibly following a slight lowering of sea level

after 5100 ± 70 yr B.P., and presently these deposits are coated by alluvium and wind blown sand. Similar environmental conditions occurred in the Palalla-Weligama area.

Conclusions

The ^{14}C dates of emerged corals in the southwest and south coasts of Sri Lanka reveal

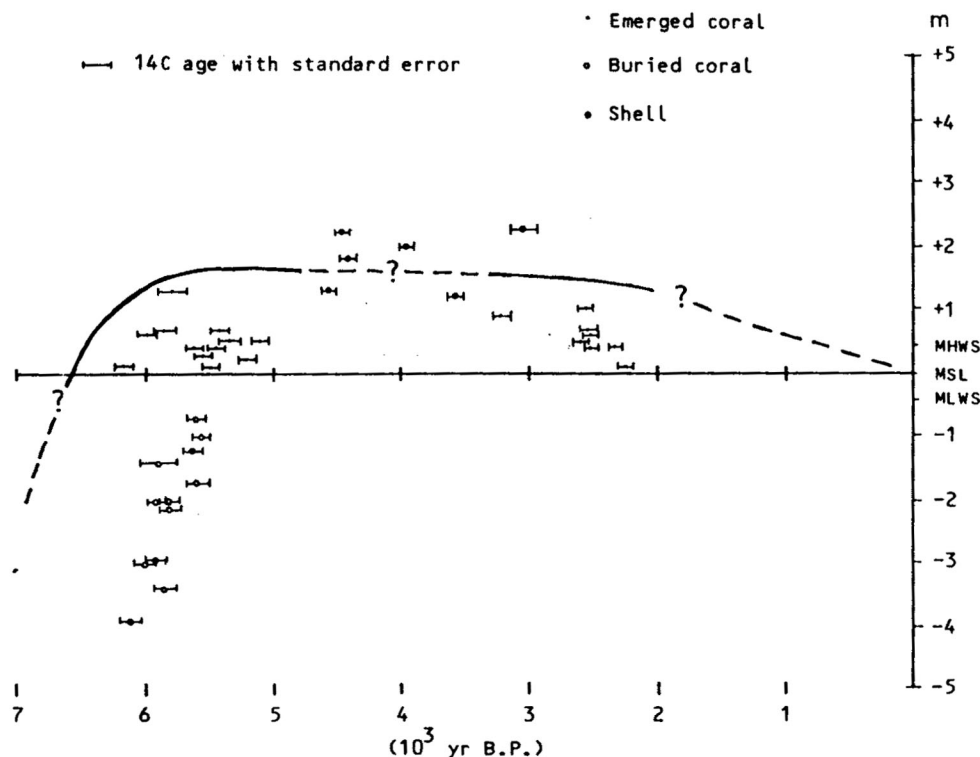


Fig.11. Mid- and late-Holocene sea level change in Sri Lanka.

that there are two different age groups connected with high sea levels during the Holocene (6170 ± 70 – 5100 ± 70 yr B.P. and 3210 ± 70 – 2330 ± 60 yr B.P.). Comparing the ages and heights of the samples with the present MLWS level, it is concluded that the former MSL in both groups was at least 1.0 m or more higher than the present MSL. The ages of buried coral deposits (6110 ± 80 – 5560 ± 70 yr B.P.) indicate that they thrived in bays or lagoons following the transgression at the beginning of the mid-Holocene. The lack of emerged coral dates between the above two age groups suggests that a slight lowering of sea level occurred, but considering the ^{14}C dates of shell deposits it is also supposed the sea level was not lowered between these two age groups.

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