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Evolution and Geological Significance of Holocene Emerged Shell Beds on the Southern Coastal Zone of Sri Lanka

Jinadasa Katupotha

Department of Geography
University of Sri Jayewardenepura
Gangodawila, Nugegoda
Sri Lanka

ABSTRACT

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Assemblance of bivalve and univalve molluskan shells occur due to the eustatic and tectonic changes as well as by coastal hazards. They are a geoscientific tool in the study of former sea-levels. Along the southern coast of Sri Lanka, the bulk of the shell valves on the "Dry Zone" between Tangalle and Bundala have been piled up by severe storm wave action as mounds, in lagoon and lake bottoms, on sand dunes and headlands. Furthermore, the shell valves of lagoon, lake and channel beds (floors of marine and brackish pools) mostly accumulated *in situ* due to the lowering of sea level. The deposition sequences of some shell patches of the mounds at Udamalala and on dune deposits help to infer that the valves have been discarded by early inhabitants and animals. The stratigraphy of the shell deposits had been intermittently covered by vast quantities of coral and/or shelly sand and various types of debris moved by severe monsoon waves. The colour and the materials of the shell layers show that they are subjected to local weathering conditions. Well-polished, oval-shaped stone artifacts, stone balls, human and animal bones as well as pottery fragments mixed with these shell beds are of archaeological interest.

ADDITIONAL INDEX WORDS: *Coastal archaeology, sea-level change, wetlands, lagoon, submerged peneplain.*

INTRODUCTION

Purpose and Significance

In southern Sri Lanka, deposits of coastal embayments contain high percentages of shell fragments; they are therefore highly calcareous rather than silicaceous. Assemblance of bivalve and univalve mollusks occur due to eustatic changes as well as coastal hazards. They are a well-known geoscientific tool in the study of former sea-level stands (PETERSON, 1986). This study attempts to analyze the geological significance of the Holocene shell beds on the southern coastal zone of Sri Lanka. The study area lies within the "Dry Zone" between Tangalle and Bundala (Figure 1). The geological significance, extension and evolution of the shell beds have not been studied in detail before. Researching these aspects is of great significance for the mining of shells as a cottage industry. Furthermore, it is necessary to declare a few selected localities as a natural heritage for geological, archaeological and palaeoenvironmental research.

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METHODS

Extension of the shell beds was mapped based on detailed field investigation. The field investigation was carried out between March and December 1992. Shell and soil samples were collected from twenty locations for geologic analysis. Each sample contained 1.5–2.0 kg of shells and shell debris. All locations and sample heights were levelled to mean sea-level (msl) using TC 1600 EDM (Electronic Distance Measurement) theodolite (Set 3 B Sokkisha) by a Government Licensed Surveyor.

Colour of the soil samples and shell embedded soils was determined by the *Revised Standard Soil Colour Charts* (OYAMA, M. and TAKEHARA, H., 1967). Separation of the grain sizes of the soil samples was undertaken using *BS 410, Laboratory Test Sieve* (ENDECOTTS LTD, London, England). Before separation of grain sizes, a weighed amount of dried soil (about 125–150 grams) was treated with 20% HCl to remove carbonate material. The treated wet sample was dried in an oven at about 100 °C for at least eight hours. About 300 grams of shells were also cleaned with

10% HCl for the identification. The laboratory procedure was conducted at the Department of Geography, University of Sri Jayewardenepura. The profiles of the shell layers were drawn using Harvard Graphics. Shells were identified by the author with the help of published catalogues of shells (ABBOTT, 1991; SABELLI, 1980; HABE, 1978).

PHYSICAL SETTING AND LAND USE

Physical Setting

The study area described here stretches in the southern part of Sri Lanka within longitude 80°48′–81°16′ and latitude 6°03′–6°09′ in Ambalangoda to Hambantota topographic sheets (1:63,360). Geologically it is underlain by the Vijayan Complex of Precambrian rocks (GEOLOGICAL SURVEY DEPARTMENT OF SRI LANKA, 1982). COORAY (1984) indicates that the western bank of the Walawe Ganga lies on the Highland Complex rocks (undifferentiated rocks), while the eastern bank lies on the Vijayan Complex (charnokite and charnokitic gneiss). The zone of the Quaternary deposits here are also somewhat narrow due to the extension of low hills and ridges close to the sea and lie on the Highland Complex and Vijayan Complex rocks.

The tide in Sri Lanka is ranging from highest spring tidal level at +87 cm to lowest neap tidal level at −9 cm in relation to the mean sea-level (datum: 0.38 cm below msl, *Colombo, The Indian Tide Tables for the Year 1993*). The tidal range at Colombo is somewhat greater than at other coastal stations. It is least around Delft and Trincomalee. Different levels between supra tidal and subtidal zone control the extent of landforms such as beaches, marshes and mangrove swamps of the landward and coral reef and sea grass beds of the nearshore zone.

The extension of the whole shell beds along the southern coastal zone is laid on Lowland 1 (Flat Terrain, below 30 m). It has a slope of ½° or 1° (60:1 or 100:1 in gradient). This is somewhat wider than the coastal belt which is between south of the Kelani Ganga on the west coast and the Nilwala Ganga on the south coast. Both monsoons blow parallel to the coast rather than across it, and the waves are largely constructive southerly swell (SWAN, 1982). The coastal belt from Tangalle to Bundala is formed of narrow and long barrier beaches and beach ridges. Dune bearing barrier spits are common features at the estuary of the Walawe Ganga and the circular shaped la-

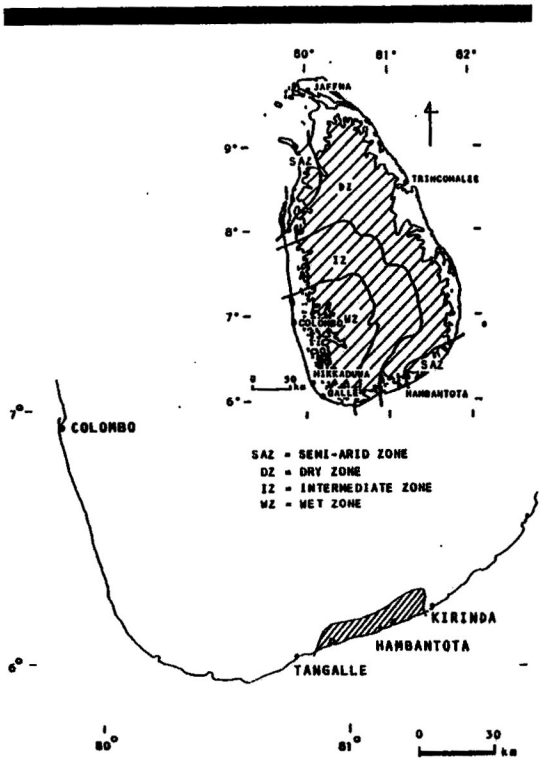


Figure 1. Location map of the shell bed areas along the southern coastal zone of Sri Lanka.

goons. Garnet and ilmenite sands are found in most shore deposits along the beach. Well-drained and imperfectly drained soils occupy these areas.

The wetlands are covered by lagoons and lakes with salt marshes and mangrove swamps behind them. The lagoons and lakes (known locally as "Lewayas") are not fed by large streams. Most of them are very saline due to the persistent winds and dry climatic conditions. These conditions have been created by rapid evaporation. The shells are highly concentrated as pockets around the Kalametiya Kalapuwa, Hungama and Lumnama Kalapuwa; Mahasittrakala Lewaya; the area between Karagan Lewaya and Pallemalala and the area between Embilikala Kalapuwa and Bundala Lewaya (Figure 2).

Based on elevation and the composition of the deposits, the lowlands can be grouped into three morphological units (KATUPOTHA, 1992a) *viz:*

(a) Flat Terrain (Lowland I, < 30 m, slope is ½° or 1° (60:1 or 100:1 in gradient). The coastal belt in Flat Terrain has been altered by terrestrial, aeolian and marine processes. Sand spits, salt pans,

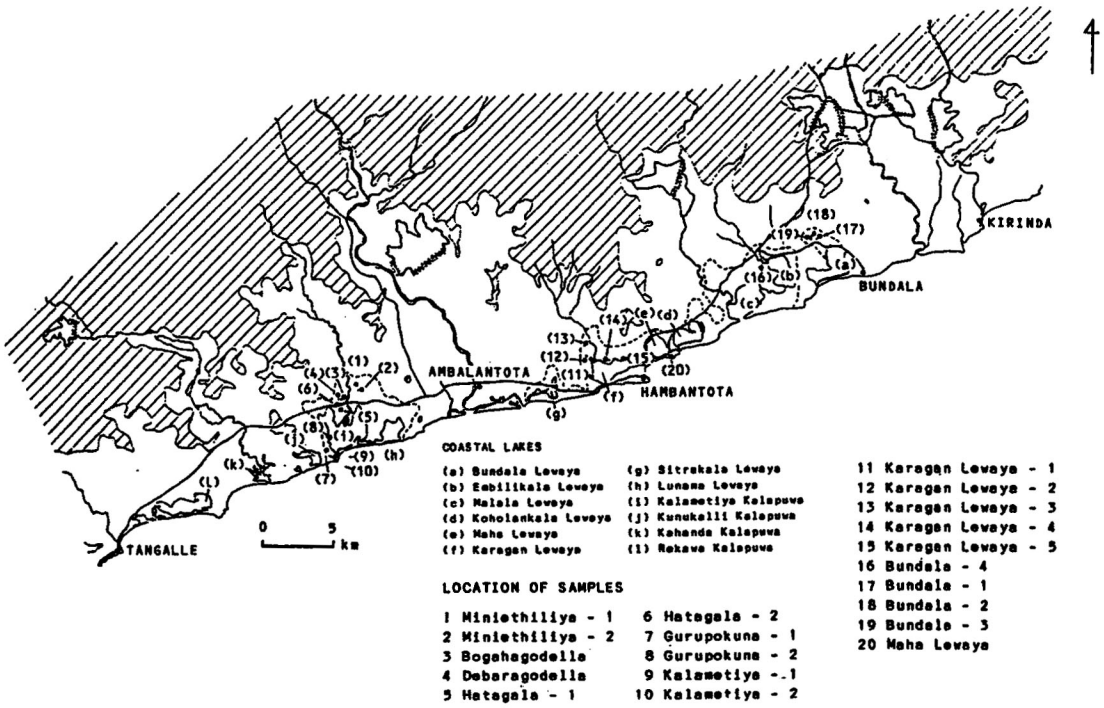


Figure 2. Extension of marine shell beds along the southern coastal zone.

salt marshes, mangrove swamps and mound topography (a hummock relief) are common features at the estuaries and their environs of the Walawe Ganga (river) and lagoons. The bedrock outcrops are too small and of low-height and appear as inselburgs. Well-drained and imperfectly drained mixed aeolian, residual and alluvial soils occupy in the Flat Terrain.

(b) Flat to Slightly Undulating Terrain (Lowland II, < 30 m) has 1° to 3° slope or 60:1 to 20:1 gradient and can be designated as "flood plain". The deposits of natural levee and flood plain of the lower Walawe Ganga basin comprise of well-drained soils. Slightly undulating topography in this terrain exhibits of different landforms such as channel scars, slip-off slopes, natural levees and slackwater areas, but rock knob plains appear sometimes above 30 m from the mean sea-level on the low planation surfaces. Stony-gravel surfaces in the area have well-drained to imperfectly drained soils. The Clay strata of the lagoon beds and just below the gravel beds have a high plasticity when wet. The gravels have a high proportion of gem-bearing minerals.

(c) Undulating Terrain (Lowland III, 30–150 m, slopes have 3° to 8° slope, 20:1 to 10:1 in gradient). Slightly undulating, undulating and rolling features appear particularly behind the Lowland I and II, around the area between Udawalawe and Ridiyagama. In the area around Timbolketiya and towards the east of Timbolketiya, the relief forms slightly undulating to moderately undulating terrain with well-drained soils. The rock knobs of the area rise from the surrounding plain, usually gently but sometimes abruptly, with steeper dome-like outcrops protruding 5 to 10 m above the general surface.

According to Koppen's classification, the southern coastal zone, from Matara to Bundala is included into "Afw"i, Amw"i" and 'Asi' climates (THAMBYAPILLAY, 1960). Meteorological data at Hambantota Station shows that annual temperature range between 27 and 30 °C and high precipitation occur during convectional cyclonic depressions (October to November), rather than the southwest monsoon (May to September).

Main soil types of the study area have a close relationship with geologic characteristics, micro

relief and seasonal distribution of rainfall. Based on *The Soil Map of Sri Lanka* (1977), the main soil groups of the study area are recognized as follows:

(a) Reddish Brown Earths with high amount of gravel in subsoil & Low Humic Gley Soils
(b) Reddish Brown Earths & Solodized Solonetz (both (a) and (b) types cover on the undulating terrain)
(c) Alluvial Soils of variable drainage and texture on flat valley bottoms, water logged areas, *etc.*
(d) Regosols (recent beach and dune sand; barrier beaches, beach ridges, sand spits and dunes along the coast are formed by such material).

Rocknob plains and erosional remnants in the coastal plain are formed by granitic gneiss, quartzite, hornblende gneiss and hornblende–biotite gneissic rocks.

The shell beds are mainly extended in coastal embayments, lagoon floors, mounds and coastal dunes in the Flat Terrain (Lowland 1) beyond the western and eastern sides of the Walawe Ganga where the above mentioned physical factors are recognized.

Land Use

The distribution and extent of the land use of the "Dry Zone" on the southern coast is fairly different from that of the "Wet Zone" on the western and southwestern coasts. The coastal lowlands are covered by barren lands mainly sand dunes which are active and migratory. Such areas were not studied in detail and were considered unsuitable for agriculture. Field investigation reveals that most of the dunes are covered by creeping vegetation as well as stunted trees such as *Spinifix littoreus* and *Ipomoea pes-caprae* and scrublands such as *Cassia auriculata* (Ranawara), *Feronia limonia* (Divul), *Dichrostachys cinerea* (Andara), *Carissa spinarum* (Karamba), *etc.* Among the trees scattered within the scrublands are *Manikara hexandra* (Palu) and *Nerium odorum* (Veera). The wetlands behind the sand dunes are occupied by mangroves along the estuary of the Walawe Ganga and around lakes and lagoons.

Salt-pans, salt and brackish water lakes of the area are subjected to daily tidal fluctuations. *Sonneratia alba* (Kirilla) is the dominant species of the area. Among other important mangroves are *Nypa fructicans* (Ginpol) which extended along edges of lagoons and tidal creeks and the *Rhizophora* (Kadol), *Bruguira* (Sirikanda) and *Ceriops* (Kaduru) spp. Lowlands which are slightly above the mean high water springs level appear as freshwater marshes. Brakishwater and freshwater marshes are widely occupied by *Typha angustifolia* (Hanmbupan), along the lower part of the Walawe basin (KATUPOTHA, 1992a).

The undulating and low ridge and valley topography (30–150 m) behind the coastal lowlands are covered by sparsely used croplands, homesteads and chena (shifting) cultivation as well as dry zone thorny forests. The paddy lands (rice fields) are concentrated in fairly wide valley bottoms to the south of the Ridiyagama Tank and the area north of Angunakolapalessa.

THE LAST-GLACIAL MAXIMUM (LGM), HOLOCENE EPOCHS AND THEIR EVENTS IN SRI LANKA

During the LGM *ca.* 18,000 yr BP, the sea surface circulation pattern of the Indian Ocean was significantly different from the modern pattern and the southwest monsoon wind prevailed weaker than today (PRELL *et al.*, 1980). WILLIAMS (1985) described that towards 18,000 yr BP the salinity gradient in the Bay of Bengal was very much higher than today, reflecting a drastic reduction in freshwater input from rivers. Accordingly, the climate was drier and windier over much of tropical Africa, Australia and South Asia with less rain in summer and stronger monsoon winds in winter. KOLLA and BISCAVE (1977) prove that the amount of quartz transported in the terms of atmospheric dust from the Arabian and Australian deserts into the adjoining oceans was greater than at present during the LGM.

The post-Glacial transgression (PGT) appears to have started around 18,000–17,000 yr BP from about 120 m below the present level and lasted about 10,800 to about 10,300 yr BP. The sea-level remained above or close to the present level during the mid-Holocene, *ca.* 5,000–6,000 years ago (FAIRBRIDGE, 1961; GILL, 1961; MÖRNER, 1969, 1982; WALCOTT, 1972). The general form of the sea-level/time curve is asymptotic, showing a rise of approximately 1 m/100 years at first then showing to 2 or 3 cm per 100 years at 7,000–5,000 yr BP (PETHICK, 1984).

DERANIYAGALA (1958) regards the heavy tectonic actions such as faulting, tilting, dislocation and block hosting which occurred during the Pleistocene as having caused the mixing of fossils of different ages to occur in gem bearing deposits in Sri Lanka. The eustatic and the climatic se-

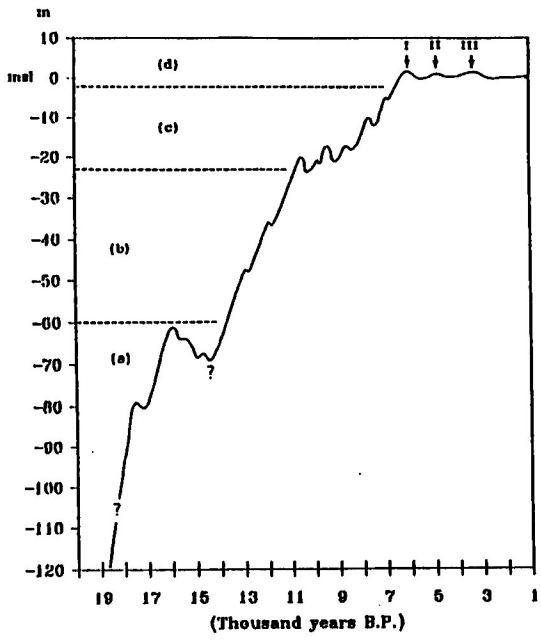


Figure 3. Eustatic oscillations in Sri Lanka since last-Glacial Maximum. (a) Development of coralline algae, limestone and calcareous sandstone reefs on the continental shelf; (b) submergence of river valleys and development of marine terraces; (c) submergence of river valleys and coastal forest; formation of 25 m, 18 m, 10 m, and 2 m levels of beachrock in the nearshore zone; (d) three episodes of high sea-levels (about 1.5 m) higher than at present; development of coastal lagoons and lakes, estuarine deposits, inland buried coral deposits, emerged coral reef patches, inland shell deposits, present beachrock and coastal swamps; 1, 11 and 111 = three episodes of high sea-level (KATUPOTHA, 1993).

quence of the Pleistocene are also identified on the basis of faunal elements from middle Pleistocene to Holocene.

In the submerged peneplain which is bounded externally by the 100 fathom isobath (*ca.* 180 m), remains of channels of some larger river channels and sunken forests in the present western and northwestern continental shelfs can be identified (DERANIYAGALA, 1958). WICKRAMARATNE *et al.* (1988) reported that the western continental shelf consists of predominately sand sized particles, 2 mm to 0.067 mm in diameter, composed of lithogenic quartz and biogenic carbonates. Most shelf sediments had been deposited in shallow water during the last low stand of sea-level and recent sediments are found accumulated 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 and canyons. This has resulted in the absence of calcareous skeletal material in the outer shelf area.

On the basis of weathering conditions, the colour and constituents of the sand and height of the beach ridges can be used as indicators to the study of the evolution of coastal lowlands of Sri Lanka (KATUPOTHA, 1988a). Based on ^{14}C dates of geologic samples (KATUPOTHA, 1988b,c) and published evidence, KATUPOTHA (1994) recognizes five stages in the Late Pleistocene and Holocene events as follows:

(a) Stage 1: From Late Pleistocene to Early Holocene. According to WAYLAND (1919), a desert-like condition occurred in much of the low country. Archaeological sites of the coastal lowlands show that the human artifacts of early stone-age (Palaeolithic) man were overlain by these wind blown brick red coloured Red Beds and Brown Earth beds. Based on ^{14}C dates SPATH (1985) observed fossil humans' horizons at Weuda of Kandy, formed about 24,300–22,100 yr BP age, and this period probably corresponds to a dry climatic phase and lower sea-level during the LGM of Sri Lanka. It can be speculated that low-lying ridges, well-marked troughs and different levels of marine terraces between the continental slope and present coastline have been formed due to the rapid rise of sea-level from *ca.* 17,000 yr BP (Figure 3). Recent oceanographic investigations reveal that the coralline algae, limestone and calcareous sandstone had been developed gradually on those features. It is suggested that the desert-like conditions during the LGM of the low country is very similar to the Pleistocene aridity in tropical Africa, Australia and Asia which was described by KOLLA and BISCAVE (1977), PRELL (1980), WILLIAMS (1985) and GIRESSE (1987). Thus, the climatic and sea-level changes, geological formations and cultural phases during the Late Pleistocene and Early Holocene Epochs in Sri Lanka followed the dry climatic conditions.

(b) Stage 2: Mid-Holocene Period (first episodes of high sea-level; 6,240–5,130 yr BP). Recently obtained ^{14}C dates of emerged coral samples from the west, south and east coasts by KATUPOTHA (1988a,b), KATUPOTHA and WIJAYANANDA (1989) and WEERAKKODY (1992) indicate that the mid-Holocene sea-level was at least 1.5 m or more above that of the present level in the above mentioned region. This sea-level variation in this pe-

riod can be correlated with India and other islands in the Indian Ocean (KATUPOTHA, 1990). Due to this transgression, the former drainage basins were submerged and headland-bay-beaches were created. As a result, corals (presently being buried between Akurala and Matara) thrived in former lagoons where factors were suitable for growth of coral gradually formed coral reefs in many places on the southwest coast, and early Holocene coastal forests were drowned by the PGT.

(c) **Stage 3: First Phase of the Late Holocene (4,390–3,930 yr BP, second episode of high sea-level).** Between the Stage 2 and Stage 3 the sea-level around 4,700 yr BP was slightly below the present position. The living coral colonies and shells of the lagoons and estuaries were buried by mud, alluvium and other debris which were washed down into the embayments by terrestrial waters. Furthermore, the shell beds were intermittently covered by vast quantities of coral sand and coral debris moved by severe monsoon waves.

(d) **Stage 4: Late-Holocene (3,280–2,270 yr BP, third episodes of high sea-level).** Between the Stages 3 and 4, the sea-level around 3,600 yr BP was also at or below its present level. It is suggested that the beachrock, slightly above supratidal level zone along the coast formed during this stage. ^{14}C dates of shells embedded in emerged reef patches, buried and emerged corals, shell beds and beachrock prove that the climatic changes have occurred after the mid-Holocene high sea-level. Further, ^{14}C dates of shell deposits along the southern coast in the Hambantota district also prove that such changes have occurred during the Late Holocene.

(e) **Stage 5: Recent Beaches and Sand Spits, *etc.*** BRYANT (1987) explains that there has been a relationship between CO_2 warming, rising sea-level and retreat of coasts in both hemispheres since 100 yr BP (AD 1850). FAIRBRIDGE'S (1961) studies also indicate the rise of sea-level and glacial retreat since 100 yr BP. As a result of these global changes, the secular and seasonal changes of land and sea have occurred along the present coastline of Sri Lanka.

The gravel deposits, Red Beds and stone tools which were already described by WAYLAND (1919), WADIA (1941), DERANIYAGALA (1958), COORAY (1967, 1984), COORAY and KATUPOTHA (1991) and DERANIYAGALA (1986) can be correlated with the long fluvial phases followed by Pleistocene interglacial stages, while shell beds in the southern coast can be correlated with mentioned Stages 3 and 4 (Late Holocene).

SEA-LEVEL INDICATORS AND THEIR SIGNIFICANCE FOR THE STUDY OF THE PALAEOSEA-LEVELS IN SRI LANKA

Sea-level indicators differ widely in indicative value (accuracy). They are important for the consideration of sea-level changes within the context of the geological development of an area (PLASSCHE, 1986). Many materials such as raised marine deposits, coastal barrier sands, beachrock, emerged and buried corals, coralline algae, marine notches, submerged forests and marine mollusks have been used from different locations in the study of sea-level changes in Sri Lanka. Former sea-level positions from barrier deposits have been discussed by ROEP (1986) for the north sea. Based on coastal geomorphology, recent coastal sediments and fossil barrier deposits, depth distribution of sedimentary structures and shells along the present coast are largely attributable to sea-level changes of the western coastal zone of Sri Lanka (COORAY, 1968; KATUPOTHA, 1985, 1988; WEERAKKODY, 1993).

Emerged beachrock reefs also provide a useful indicator of a palaeo tide level. Although it is agreed that beachrock forms within the supratidal zone, the exact upper limit to the cementation processes is uncertain. Beachrock on the west coast of Sri Lanka was formed during the Late Holocene (around 3,700 yr BP), and the submerged reefs on the terraces were formed during the early stillstands of sea-levels since LGM (COORAY, 1968; COORAY and KATUPOTHA, 1992; KATUPOTHA, 1988b,c, 1989; WICKRAMARATNA *et al.*, 1988).

Coral ecology and calcification, zonation and colonial morphology, *in situ* position, upper limit of open-water and moating during the inter-tidal level, *etc.*, are responsible for reef building to sea-level and have a specific relationship to sea-level (HOPLEY, 1986). ^{14}C dates of emerged and buried coral reef patches (most of them are in position of growth) of the western and southern coasts indicate that they have formed due to mid- and late Holocene high sea-levels (KATUPOTHA, 1988b,c; KATUPOTHA and FUJIWARA, 1988; WIJAYANANDA and KATUPOTHA, 1989).

The fossil notches may indicate both the position and approximate duration of a sea-level stand as well as the speed of the sea-level change (PIRAZZOLI, 1986). Along the southwestern and southern coasts in Sri Lanka, symmetrical notches have been developed on rocky promontories and headlands due to a gradual emergence or sub-

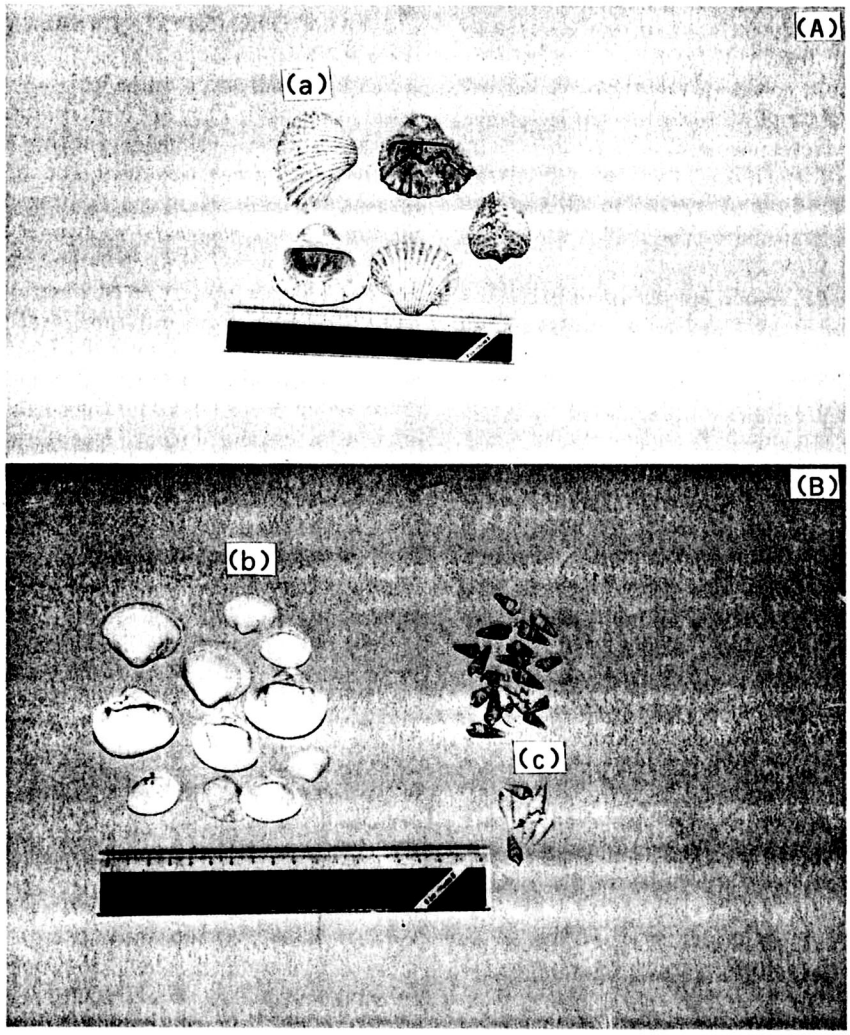


Plate 1. (A) *Anadara* (a), *Meretrix* (c) and *Cerithidea* (c) spp. contained in the shell beds along the southern coastal zone.

mergence. Profiles with heights varying 2–3 and 6–7 m were formed in this area during periods of high sea-level. However, detailed investigation regarding the sea notches is required before coming to any conclusion.

The formation of coastal peat deposits can also be applied to study of palaeosea-levels around Sri Lanka. One peat sample (*ca.* 30 cm below msl) from a foundation pit at the Galadari Hotel Complex, near the Beira Lake in Colombo has dated at 5,790 ± 80 yr BP (KATUPOTHA, 1988b). This date indicates that the PGT has culminated during the first phase of the Holocene transgression. Fine to medium grained sand in the upper layers of the back barrier ridges on these peat deposits were developed later by wind blown sand.

A submerged forest is also a useful indicator in the study of former sea-levels. They are defined as assemblages of tree remains in their growth position and regularly covered by the tide. Submerged forests are usually found as peat beds, containing the stumps and trunks of trees (WHITTOW, 1984). According to HEYWORTH (1986), the lowest level of the tree growth is closely re-

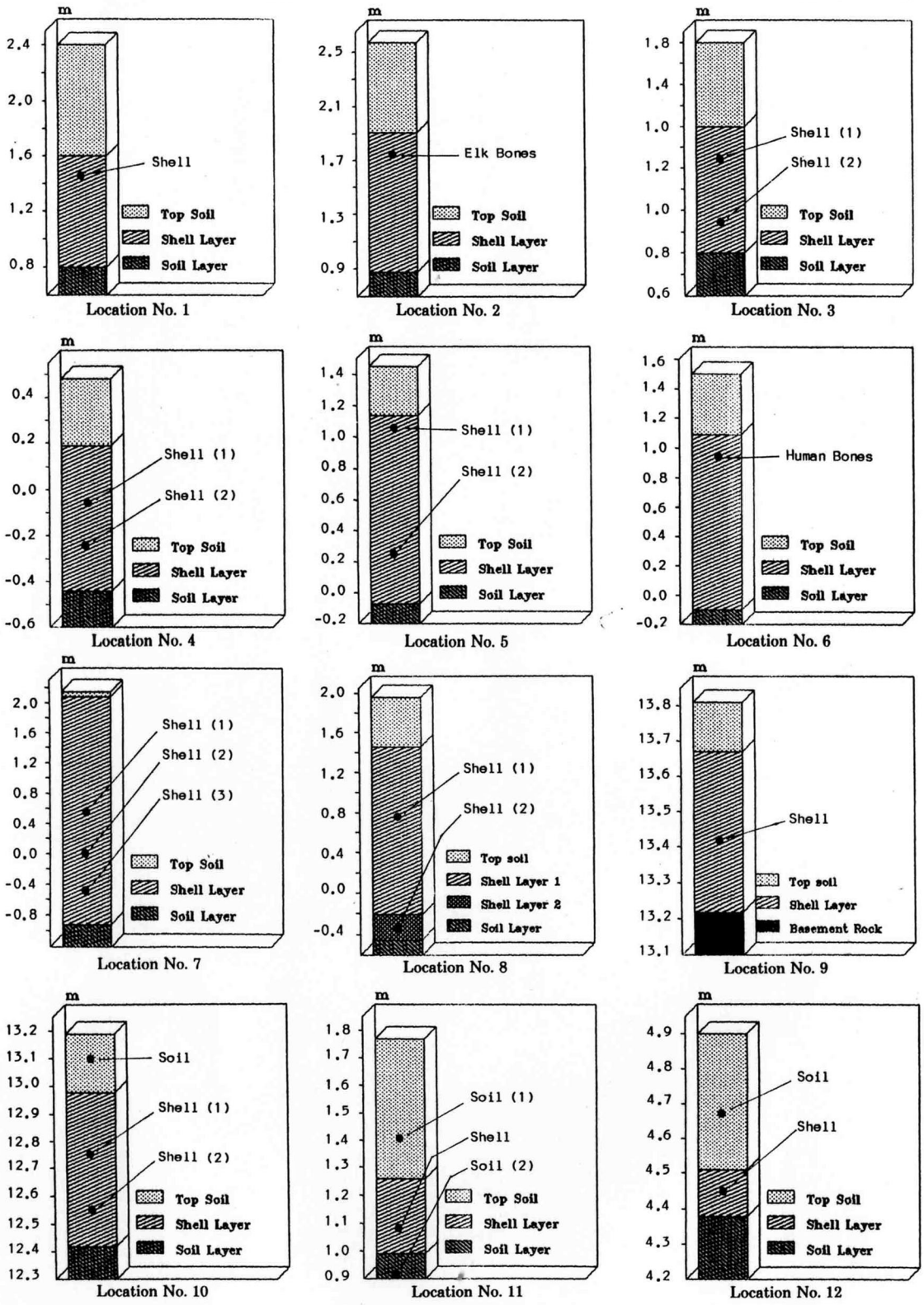
lated to a point between the local MHWS and highest astronomical tide. Although the preservation of trees in submerged forests is an accurate reflection of past sea-levels, detailed investigation and radiometric dating regarding the submerged forest are also required before coming to any conclusion.

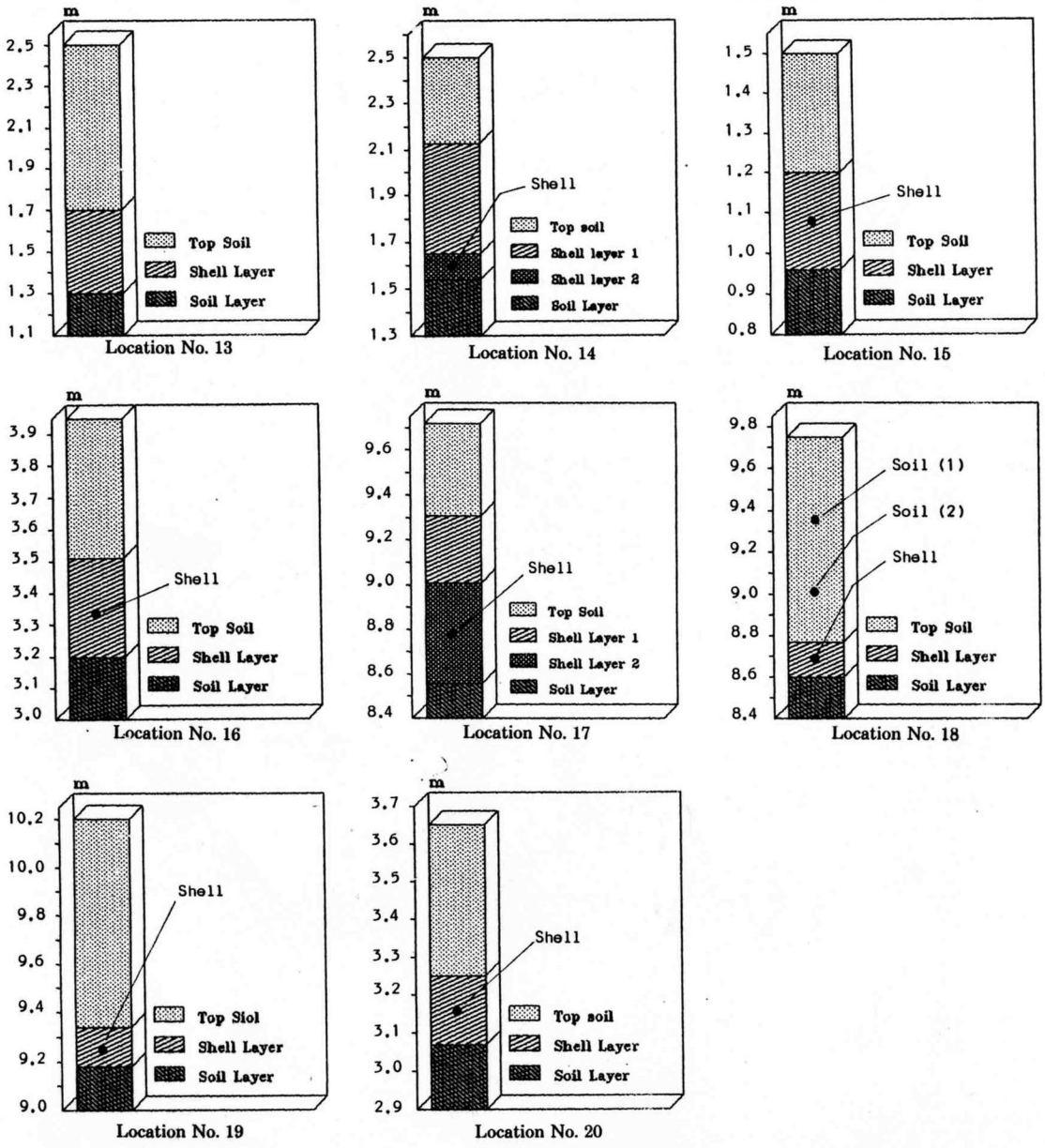
GEOLOGICAL SIGNIFICANCE OF THE SHELL BEDS ALONG THE SOUTHERN COAST

The present investigation of raised shell beds on the southern coast indicates that they have been piled up at former lagoonal embayments,

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Figure 4. Location No. 1—Hungama (Miniethiliya). Calcareous clay with few sandy soil (Grayish Gray Soil—10YR 4/2). Tiny and small to somewhat large size shells can be found. The *Cerithidea* spp. is below 20 mm and *Meretrix* spp. is below 40 mm in size. Location No. 2—Hungama (Miniethiliya). Elk bones (horn) together with *Meretrix* spp. were found. Shell debris, sub-rounded quartzite pebbles, coarse to fine sand with clay and other animal remains are embedded in the deposits (Plate 1). The shell beds of the area are about 4 kilometres inland from the present coast. Thickness of the bed is considerably high. Location No. 3—Hungama (Bogahagodella). Shells, shell rubble in Sample 1 are mixed with calcareous sand and clay (Light Gray—10YR 7/1). The shells of Sample 2 are mixed with Brownish Gray soil (10YR 4/1). Pure quartz pebbles were found in this sample. The *Cerithidea* spp. and *Meretrix* spp. are below 20 mm in size. Location No. 4—Hungama (Debaragodella). The shells are mixed with calcareous clay and Brownish Gray soil (7.5YR 4/1) in Sample 1. There are no pebbles or coarse sand, but pure quartz fragments are found. Calcareous clay with fine sand (Grayish Brown soil—7.5YR 4/2) and shells were in Sample 2. The clay was compact when dry. The clams in position of life were also found in Location No. 4. Location No. 5—Hatagala (Temple Land). Tiny and small size to large size of shells gathered together with Light Gray sandy soil (10YR 7/1). Many *Cerithidea* spp. are well preserved and they are below 20 mm in size. *Meretrix* spp. of both samples are also below 55 mm in size. A thick shell layer has been mixed with stone pebbles (appear as artifacts), human bones, pieces of pottery, *etc.* Location No. 6—Hatagala (Temple Land). Highly weathered human bones such as parts of jaws with teeth, vertebral columns, rib cages and radius are found from the same mound of Location No. 5. The last teeth of the jaw indicate that the skull belonged to a young human. Other conditions of the site are similar to Location No. 5. Location No. 7—Bataata (Gurupokuna 1). Sample 1—Light Gray shelly sand (10YR 7/1). Clear quartz fragments (rare) were in the sample. *Meretrix* spp. and *Cerithidea* spp. of the sample are below 35 mm. Sample 2—Light Gray shelly sand (10YR 7/1). The *Meretrix* spp. is small (below 30 mm) and *Cerithidea* spp. appear as fragments. Unidentified shell fragments are also found. Sample 3—Dull Yellowish Orange soil (10YR 6/3) appeared. *Meretrix* spp. is below 50 mm. Weathered *Cerithidea* spp. is below 20 mm. Location No. 8—Bataata (Gurupokuna 2). Sample 1 is mainly composed of Light Gray Sandy Soil (10YR 7/1) and shells. *Meretrix* spp. is below 40 mm in size. Sample 2 is formed by Dull Yellowish Brown Soil (10YR 4/3), sand and shell rubble. *Cerithidea* spp. of sample 2 is below 20 mm. The *Meretrix* spp. and *Anadara* spp. are below 45 mm in size. Location No. 9—Kalametiya 1. The shells *Meretrix* spp. are below 40 mm in size. Broken large shells mixed together with Brown Soil (10YR 4/3). Pottery fragments are also found. The shells are gathered even in rocky splits. Based on the deposition pattern there is a possible indication that shells were deposited in the area due to severe storm wave action. Location No. 10—Kalametiya 2. Brown fine sand with clay (10YR 4/3), shell and shell fragments appear in both shell samples. The shells belong to *Meretrix* spp. (below 40 mm in size). Other comments are same as Location No. 9. Location No. 11—Karagan 1 (Hunukotumulla). Sample 1 is formed of 7.5YR 4/2 Grayish Brown medium to fine sand clay soil. Somewhat compact layer has weathered pebbles of iron. Sample 2 has Grayish brown soil (7.5YR 4/2). *Meretrix* spp. is below 40 mm in size. Three shells are found in position of life (30 mm below in size). Somewhat compact, Sample 3 is Grayish Yellow Brown (10YR 4/2) in colour. Calcareous clay patches and weathered ironstone pebbles are found. Location No. 12—Karagan 2 (Hunukotumulla). The shells mixed with Brown soil (7.5YR 4/3), fine sand and calcareous materials. Pebbles are very few. Plant remains are evident. *Meretrix* spp. is below 45 mm, *Anadara* spp. is below 65 mm in size. Location No. 13—Karagan 3 (Arabokka). The shell layers of the area composed of Dull Yellowish Brown Soil (10YR 5/4) with fine sandy clay and shelly sand. *Meretrix* spp. of the sample is varied from small to somewhat large (below 40 mm). Location No. 14—Karagan 4 (Nelumpathvila). The shell layer composed of Dull Yellowish Brown Soil (10YR 5/4) with fine sandy clay and shelly sand. *Meretrix* spp. is somewhat large (below 40 mm). Location No. 15—Karagan 5 (Nelumpathvila). Sample 1—Brownish gray soil (10YR 6/1) with calcareous sand and clay. The shell layer composed of Dull Yellowish Brown Soil (10YR 5/4) with fine sandy clay and shelly sand. *Meretrix* spp. of the sample is somewhat large (below 40 mm). Location No. 16—Bundala (Embilikala). The shells contained Grayish Brown Soil (7.5YR 4/2) with fine sand and clay, weathered pebbles, quartz fragments, plant remains. *Meretrix* spp. is below 45 mm and weathered *Cerithidea* spp. appeared as fragments. Location No. 17—Bundala Road 1 (near 4th km). Dark Brown medium sand to fine sand with clay soil (7.5YR 3/3) of sample is somewhat compact. Plant roots and other organic matter are found. Damaged and weathered *Meretrix* spp. and *Cerithidea* spp. are below 30 mm in size. Location No. 18—Bundala Road 2 (near 4th km). Dark Brown medium to fine sand with clay soil (7.5YR 3/3) of Samples 1 and 2 are somewhat compact. Plant roots and other organic matter are found. The shells (Sample 3) have deposited with Grayish Brown Soil (7.5YR 4/2), medium to fine sand, calcareous clay and feldspar pebbles (rare). *Meretrix* spp. below 30 mm and weathered *Cerithidea* spp. are below 30 mm in size. Location No. 19—Bundala Road 3 (near 4th km). Stratigraphic conditions, types of shells and embedded soils of the location are same as Locations 17 and 18. Location No. 20—Maha Lewaya (Koholankala). Shells are mixed with Dull Yellowish Brown Soil (10YR 4/3) with calcareous clay. Well preserved *Meretrix* spp. of the sample is below 35 mm in size.


m
2.4
2.0
1.6
1.2
0.8
Shell
Top Soil
Shell Layer
Soil Layer
Location No. 1
m
2.5
2.1
1.7
1.3
0.9
Elk Bones
Top Soil
Shell Layer
Soil Layer
Location No. 2
m
1.8
1.4
1.0
1.2
1.0
0.8
0.6
Shell (1)
Shell (2)
Top Soil
Shell Layer
Soil Layer
Location No. 3
m
0.4
0.2
0.0
-0.2
-0.4
-0.6
Shell (1)
Shell (2)
Top Soil
Shell Layer
Soil Layer
Location No. 4
m
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Shell (1)
Shell (2)
Top Soil
Shell Layer
Soil Layer
Location No. 5
m
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
Human Bones
Top Soil
Shell Layer
Soil Layer
Location No. 6
m
2.0
1.6
1.2
0.8
0.4
0.0
-0.4
-0.8
Shell (1)
Shell (2)
Shell (3)
Top Soil
Shell Layer
Soil Layer
Location No. 7
m
2.0
1.6
1.2
0.8
0.4
0.0
-0.4
Shell (1)
Shell (2)
Top soil
Shell Layer 1
Shell Layer 2
Soil Layer
Location No. 8
m
13.8
13.7
13.6
13.5
13.4
13.3
13.2
13.1
Shell
Top soil
Shell Layer
Basement Rock
Location No. 9
m
13.2
13.1
13.0
12.9
12.8
12.7
12.6
12.5
12.4
12.3
Soil
Shell (1)
Shell (2)
Top Soil
Shell Layer
Soil Layer
Location No. 10
m
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
Soil (1)
Shell
Soil (2)
Top Soil
Shell Layer
Soil Layer
Location No. 11
m
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
Soil
Shell
Top Soil
Shell Layer
Soil Layer
Location No. 12



alluvial mounds (hummocks) and headlands from Kalametiya to Pallemalala (Bundala).

The shells of the study area belong to mainly three families: Veneridae (Venus clams), Arcidae (Ark shells) and Potamididae (Horn shells). The Veneridae is a large and well-known family of hard-shelled clams (strong and glossy). Their cardinal teeth are well-developed and the lateral teeth are often strong. The family Arcidae are heavy, squarish, porcelaineous clams having a so-called taxodant hinge—a straight hinge with numerous small teeth, about the same size. Most common ark shell species live in warm waters in sandy or muddy areas, while a few are found near coral reefs. The shells of this family of the study area belong to *Anadara granosa* or *Anadara uropygmelana*. The Potamididae shells, including *Cerithidea cingulata* or *Cerithidea ornata*, is a large

Table 1. *Details of the Raised Shell Beds on the Southern Coast (levels in metres).*

No.	Location	Ground Level Surface	Thickness of the Shell Layer	Lower Level of the Shell Layer	Thickness of the Level	Type of the Sample and Level	Relief
1	Miniethiliya 1	2.40	0.80	0.80	0.80	shell (1.45)	mound
2	Miniethiliya 2	2.56	0.78	0.87	1.03	bones (1.80)	mound
3	Bogahagodella	1.80	0.40	0.80	0.60	shell (1.25)	mound
						shell (0.95)	
4	Debaragodella	0.48	0.30	−0.44	0.65	shell (−0.24)	mound
						shell (−0.04)	mound
5	Hatagala 1 (TL 1)	1.45	0.30	−0.06	1.21	shell (1.05)	
						shell (0.04)	
6	Hatagala 2 (TL 2)	1.50	0.42	−0.10	1.18	human bones (1.00)	mound
7	Gurupokuna 1	1.50	0.10	−0.90	3.00	shell (0.60)	rocky mound
						shell (0.06)	
						shell (−0.50)	
8	Gurupokuna 2	1.95	0.50	−0.50	1.90	shell (0.82)	rocky mound
						shell (−0.45)	
9	Kalametiya 1	13.80	0.13	13.25	0.45	shell (13.25)	headland
10	Kalametiya 2	13.20	0.20	12.40	0.60	soil (13.10)	headland
						shell (12.75)	
						shell (12.60)	
11	Karagan Lewaya 1	1.77	0.51	1.00	0.25	soil (1.40)	lag. coast
						shell (1.08)	
						soil (0.90)	
12	Karagan Lewaya 2	4.90	0.40	4.38	0.12	soil (4.70)	mound
						shell (4.45)	
13	Karagan Lewaya 3	2.50	0.80	1.30	0.40	no sample	lag. coast
14	Karagan Lewaya 4	2.50	0.37	1.54	0.56	shell (1.60)	lag. coast
15	Karagan Lewaya 5	1.50	0.30	1.00	0.20	shell (1.09)	lag. coast
16	Bundala–Embilikala	3.90	0.44	3.20	0.30	shell (3.35)	mound
17	Bundala Road 1	9.73	0.42	8.60	0.70	shell (8.80)	mound
18	Bundala Road 2	9.75	0.42	8.60	0.18	soil (9.30)	mound
						soil (9.00)	
						shell (8.70)	
19	Bundala Road 3	10.20	0.85	9.17	0.16	shell (9.25)	mound
20	Maha Lewaya	3.65	0.40	3.08	0.17	shell (3.16)	lag. coast

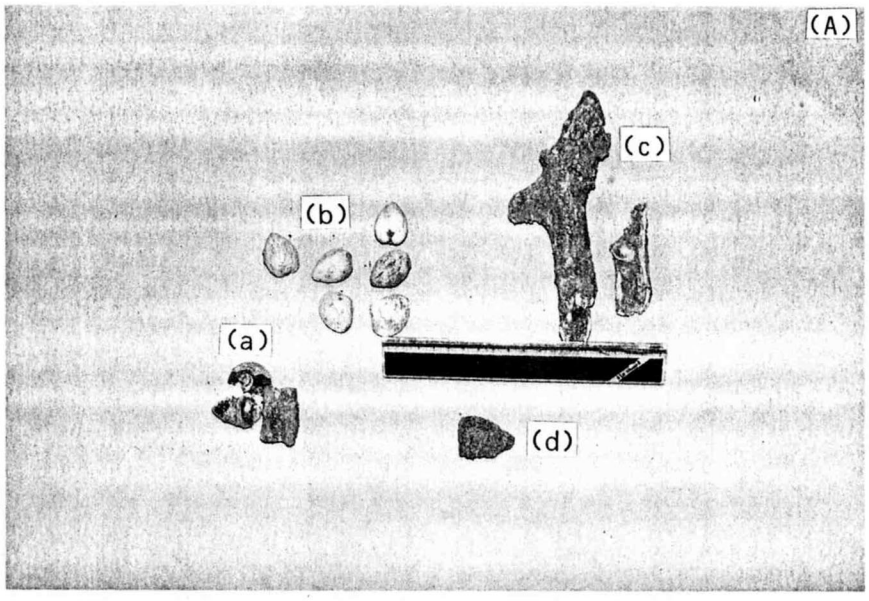
Source: Field Survey.

brackish water group with elongate, solid shells usually dirty brown in colour.

The shell valves in the beds from Kalametiya Kalapuwa to Bundala Kalapuwa belong to a few species, the dominant species of which is *Meretrix meretrix*. *Anadara* and *Cerithidea* spp. are also found mixed with *Meretrix* spp. or separately (Plate 1). Most of these are mined from paddy fields, small mounds (hummocks), former embayments and the bottoms of lagoons, lakes and creeks.

The levels of the shell layers, types of the materials and colour of the soil are described and shown in Figure 4 (Location No. 1–20). The types of shells, deposition patterns, live position of the valves, rocky artifacts, animal bones and human bones which were found from these shell beds are shown in Plates 1 to 8 (for Location sites see Figure 2). Thickness and the height of the sample location sites are shown in Table 1.

The extensive shell beds in Hatagala extend up to Miniethiliya about 4 kilometres inland from the present coast. The beds at Hatagala-Ovitigoda Yaya (paddy field) are composed of *Meretrix* spp. They are somewhat large (below 55 mm in size). Highly weathered pieces of elk bones and pottery fragments can be found from the mining pits (Plate 2A). The shells at Miniethiliya are mined from small mounds near the paddy fields and small mounds slightly elevated from the paddy fields (Figure 4, Locations 1 and 2). The patches of shell beds vary about 0.25–0.50 ha in size.



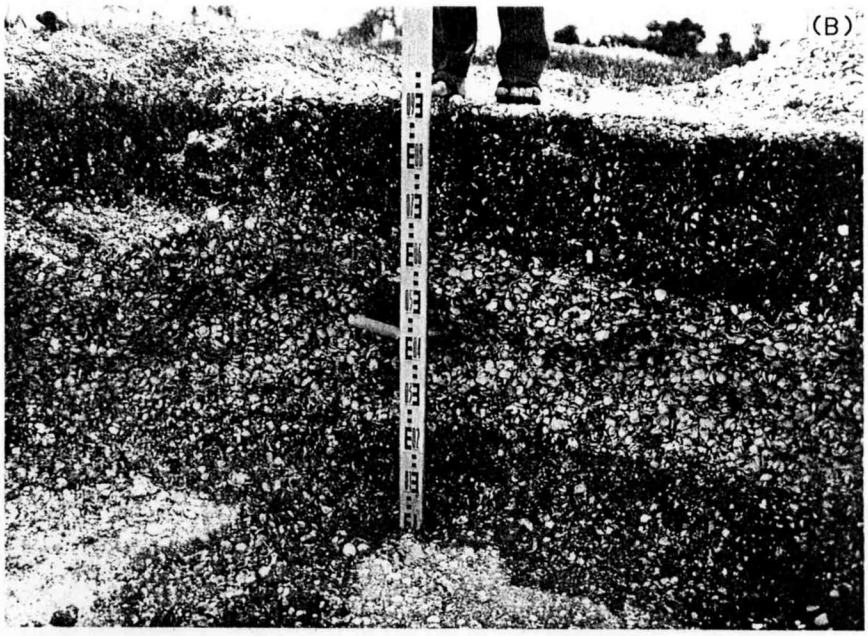


Plate 2. (A) Fired quartzite pebbles (a), *Meretrix* shells in living position (b), elk bones (c), and a piece of pottery (d), from Hungama-Ovitigodayaya paddy field; (B) About 1 m thick shell beds at Hungama-Bogahagodella (Location No. 3).

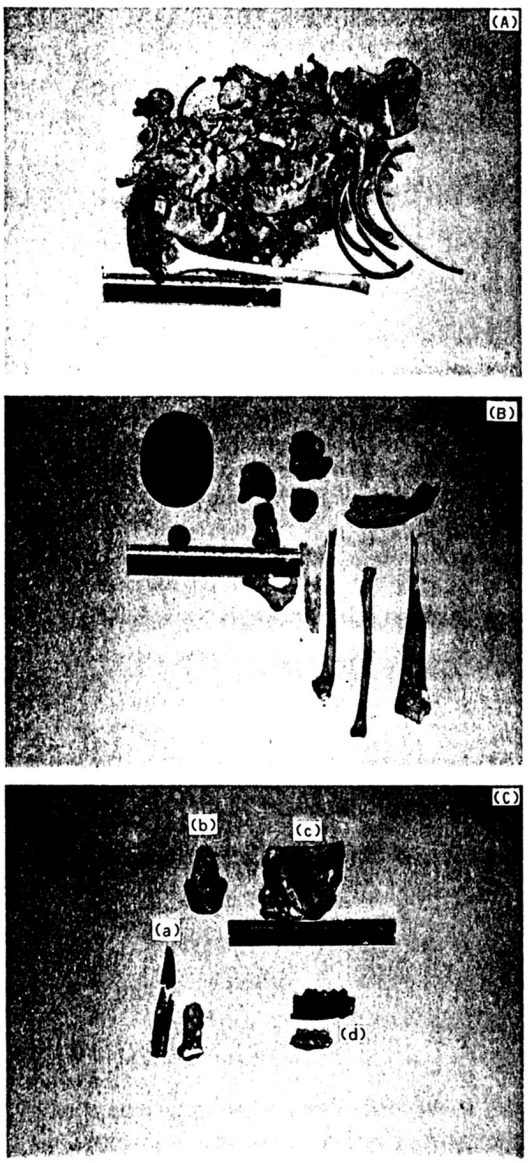


Plate 3. (A) Debris of human bones, (B) human and other animal bones and stone artifacts, (C) pieces of elk bones (a), serpent's head (b), human and other animal bones (c and d), from the shell beds at Hatagala-Temple land, Location No. 5 and 6.

The beds at Hungama-Pallegama (Ihalagama Yaya) are also mixed with univalve shells, *Anadara* spp. and *Meretrix* spp., pottery fragments and animal bones. The deposition sequence of the layers indicates that shells have been gathered along the former lagoon beaches by storm waves and in lagoon bottoms or brackishwater pools by lowering of sea-level between 5,030 and 4,390 yr BP (KATUPOTHA, 1992). Similar features are found at Hatagala-Bogahagodella in Location 3 (Figure 4, Plate 2B) and Debaragodella in Location 4 (Figure 4). Most of these shell mounds are covered by thorn bushes and stunted trees.

A coconut land at Hatagala (Temple Land, about 0.25 ha in size), has a considerable amount of shells (Figure 4, Locations 5 and 6). Well polished oval-shaped stone artifacts, stone balls, human bones, a head of a serpent and other animal bones as well as pottery fragments are mixed with these shell beds (Plates 3A, 3B, 3C and 5A). The materials of the shell beds represent that they have been piled up by storm waves.

There are two distinctive beds at Bataata-Guropokuna and Kalametiya which have been deposited on different areas morphologically. The beds at Gurupokuna (Figure 4, Locations 7 and 8) appear as about 3 m thick deposits on mounds and a former lagoonal beach. The horizontal deposition pattern indicates that the valves have been piled up by storm waves (Plate 4A and B), while the Kalametiya-Henagahapugala beds (Figure 4, Locations 9 and 10) were deposited on a rocky headland (with a thin soil cover) which is about 14 m high from the msl. Many pieces of pottery mixed with the shell bed in this area (Plate 5B) are also gathered by storm waves. The thickness and the height of these shell beds are fairly different to other locations (Table 1). Grain size analysis of the Location No. 10 contain above 75 percent sand below 0.60 mm. The soil layer of this location is about 0.20 cm thick and contains 16.54 percent organic matter.

Micro-layers of a shell bearing bed at Kalametiya (unlevelled site to the east from Locations 9 and 10) on a former lagoon bottom contain *Meretrix* and *Cerithedea* spp. (Plate 6). Tiny and small to large shells (below 40 mm in size) of *Meretrix* and *Cerithidea* spp. with calcareous sand layers had been piled up by wave action, while the lower layers contained weathered shells and shell fragments. They are mixed with weathered organic material (10YR 2/1) and calcareous clay. The bluish clay of the bottom layer indicates that the shells were deposited on a grass biomass. Such grass materials indicate that a backmarsh was developed sometimes prior to the first episode of high sea-level rise (KATUPOTHA, 1992b).

The shells from Godawaya to Mirijjawela are

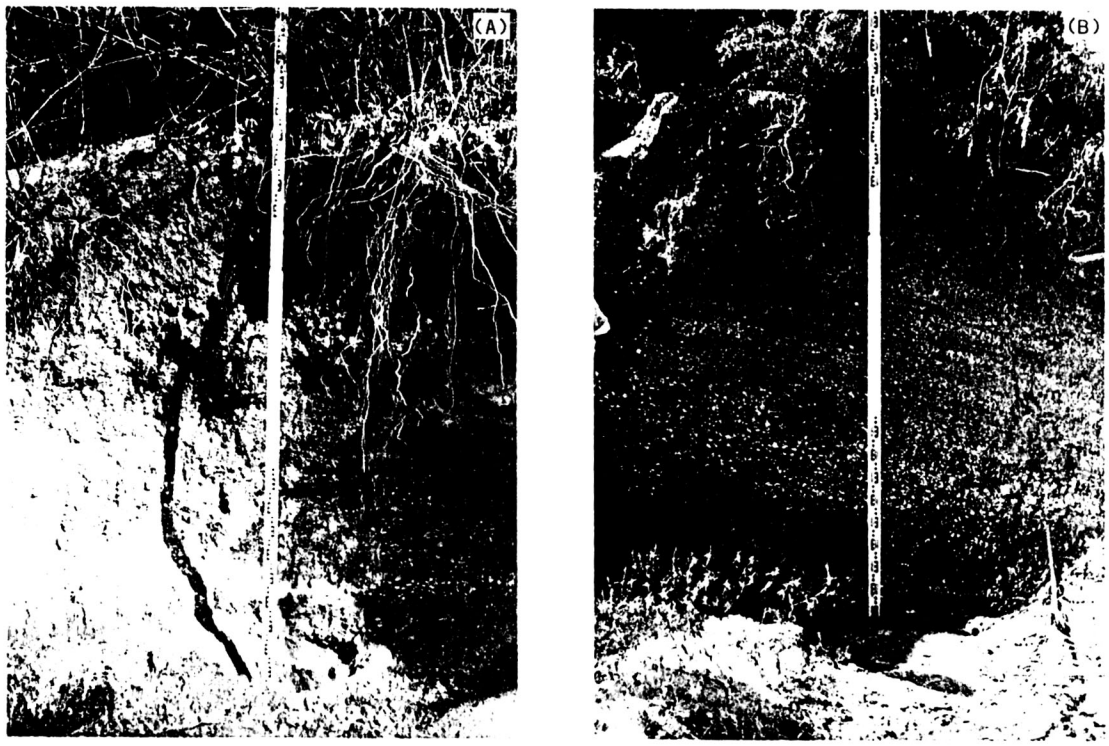


Plate 4. (A and B) Horizontal deposition patterns of the shell beds at Bataata-Gurupokuna indicate the shell valves have piled up by severe storms (Location No. 7 and 8).

deposited as small pockets in depressions (lagoon and lake bottoms) and sandy mounds which gradually increase in altitude inland. The beds at Kiula Kalapuwa (lagoon) consist of tiny and small to large *Meretrix* spp. They are below 50 mm in size. The top soil of the area is covered by dull, yellowish brown medium to fine sand. The soil layer which is below the shell layer contains medium to fine brown soil. Particle sizes and the composition of the soil suggest that they were deposited by aeolian process. Somewhat large shell beds are found at Hunukotumulla (Figure 4, Locations 11, 12 and 13), Arabokka (Figure 4, Location 14) and Nelumpathvila (Figure 3, Location 15) on former lagoon beaches. At a lagoon around the Karagan Lewaya, they can presently be seen as mounds. They are also covered by thorny bushes and stunted trees. The shell pockets in the northwestern area of the Karagan Lewaya (Arabokka and Nelumpathvila) are also deposited in many places along the lagoon coast, stream and channel beds as well as on mounds with different thickness (Table 1). The organic matter of soil samples 1 and 2 in Location No. 11 contain 19.71 and 30.36 percents, respectively. The upper stratum is about 0.55 m, while the second stratum is located beneath the shell layer and contains higher organic matter (30.53 percent) than the upper. Another soil sample collected from Location No. 12, about 4.7 m high from the present msl also contains 18.56 percent organic matter. The grain size of this sample is below 0.60 mm. Deposition sequence, particle sizes and composition of the sand indicate that the soil in the area is aeolian in origin.

Extensive shell beds at Sippikulama on the eastern bank of the Maha Lewaya, Koholankala (Koholankala Lewaya), Nabadewa (northwards from the Malala Lewaya), Pallemalla and Udamalala areas are found on mounds. The Nabadewa beds are more than 4 km inland from the present coast and are composed of stone artifacts and quartzite pebbles (Plate 7). Based on the colour of the quartzite pebbles, it is possible to infer

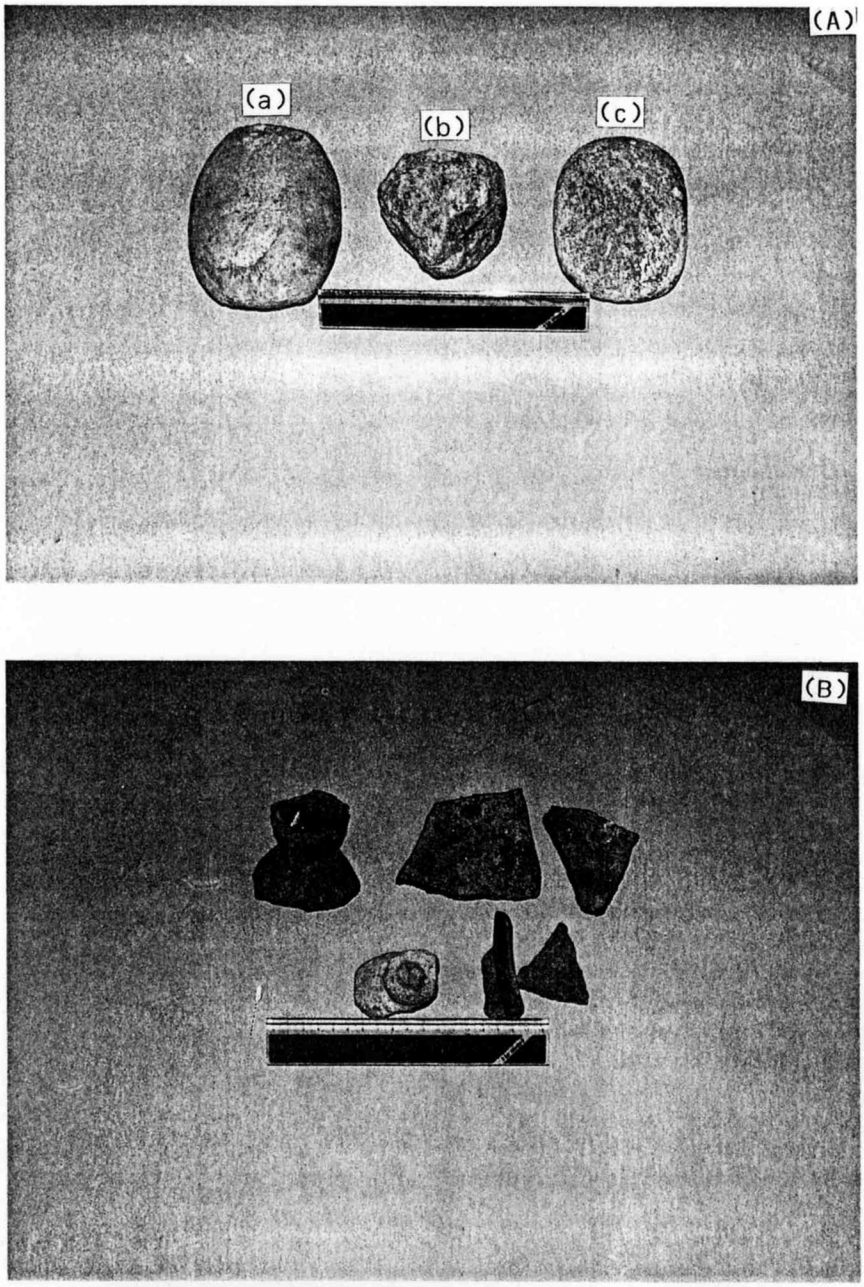


Plate 5. (A) Stone artifacts collected from the shell beds at Hatagala-Temple Land, Location No. 5 (c); Nabadewa, Location 16 (b) and Bundala, Location No. 19 (a). (B) Pieces of different types of pottery are found from the shell beds at Kalametiya (Location No. 9 and 10).

that these may have been fired. The top soil (alluvial) cover of the area is about 1.5 m thick (Plate 7), may be fluvial in origin. The shell beds in the area around Embilikala Kalapuwa too appear on mounds and ditches covered by stunted scrublands (Figure 4, Location 16). The shell beds

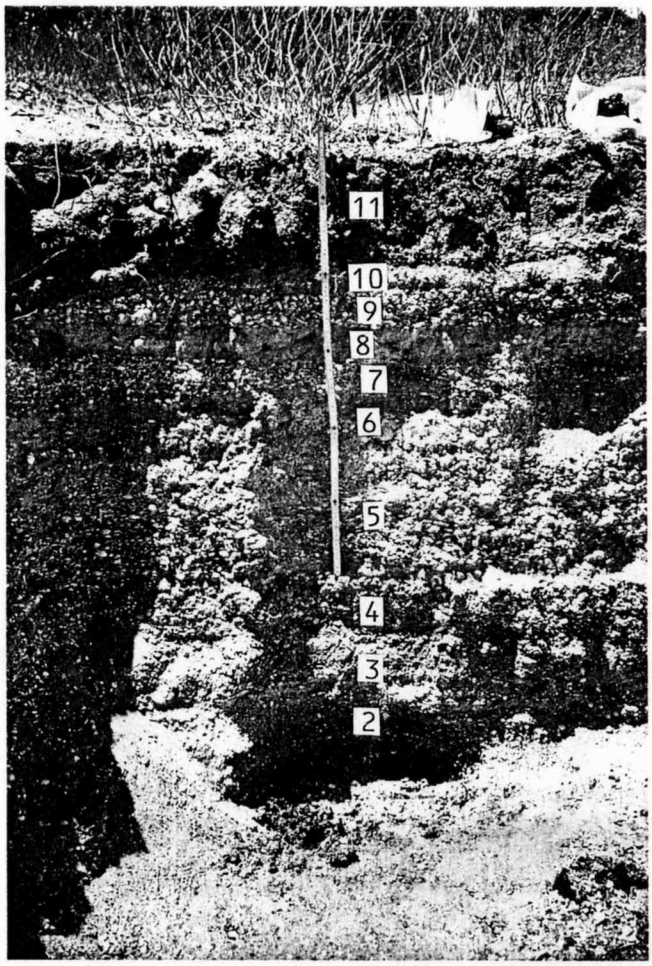


Plate 6. Stratigraphic sequence of the shell bed at Kalametiya. Eleven micro-layers (series) are identified based on the type and size of shells and constituents of the materials.

around Bundala Lewaya (Figure 4, Locations 17, 18 and 19) are somewhat high from the msl (Table 1) compared to the shell beds at Maha Lewaya and Embilikala Kalapuwa. Grain size analysis of two shell samples collected from Location No. 18 has high organic matter content. Sample 1 (9.3 m above from msl) and Sample 2 (9.0 m above from the msl) from this location contain 31.43 and 36.06 percents organic matter, respectively. Nearly 70 percent of the grains are below 0.60 mm in size with about a 1.0 m thick soil cover (Plate 8) and may be fluvial in origin. They are also deposited on former lagoon beaches. The shell beds at Koholankala (between Maha Lewaya and Koholankala Lewaya) are also not thick (Figure 4, Location 20 and Table 1) when compared to the beds at Gurupokuna, Hungama and the Karagan Lewaya.

EVOLUTION OF THE SHELL BEDS AND THEIR RELATIONSHIP TO SEA-LEVEL CHANGE

KATUPOTHA (1988a,b) dated buried coral deposits and emerged coral reef patches of the western and southwestern coasts and several shell beds on the southern coast. He indicates (KATUPOTHA, 1992b) that the mid-Holocene sea-level was at least 1.5 m above that of the present level with three episodes as follows:



Plate 7. Glossy and well preserved shells and stone artifacts (quartzite) found at Nabadewa, left bank of the Malala Ara, about 4 km inland from the present coastline. Thick fertile alluvial soils overlain on the shell beds.

(a) 6,240–5,130 BP (First episode of high sea-level)
(b) 4,390–3,930 BP (Second episode of high sea-level)
(c) 3,280–2,270 BP (Third episode of high sea-level)

Following these high sea-levels, the former drainage basins were submerged forming lagoons and lakes further inland, sometimes 3 to 4 km inland from the present coast. The undulating lobes which were extended towards the coast and outcrops became headland. As a result, headland-bay-beaches were created in many areas along the southern coast. Furthermore, the corals, presently emerged reef patches buried between Akurala and Matara, thrived in such lagoons where factors were suitable for their growth especially on the south-western and southern coasts. Mollusks lived in intermediate and dry zones, coastal lagoons and lakes. The result of the dated emerged and buried corals and shells are shown in Figure 5. The emerged coral reef patches of this area have thrived due to the consistent MHW level.

Around 3,700 yr BP, it is suggested that the beachrock which formed above in the supra-tidal zone on the west coast had developed during this stage. As evidenced from ^{14}C dates of shells embedded in emerged reef patches and corals (in growth position) from emerged reef patches (HUBBS *et al.*, 1962; KATUPOTHA, 1988b,c) the climatic changes occurred after the mid-Holocene high sea-level. The lowering of sea-level can be recognized between 5,030–4,390 years BP and 3,930–3,290 years BP.

Furthermore, the bulk of the shell valves were piled up by severe storm wave action on mounds, in lagoon and lake beaches, sand dunes and headlands. Depositional sequence and processes of these shell beds indicate that the shell valves of lagoon, lake and channel beds (floors of marine and brackish pools) mostly accumulated *in situ* as a consequence of the lowering of sea-level around 4,700 and 3,600 yr BP; and the sea was at or slightly below its present level (KATUPOTHA, 1988b,c; KATUPOTHA and WIJAYANANDA, 1989). Further, ^{14}C dates of shell beds along the southern coast in the same area indicate that they have been deposited by different means (Table 2). The coral colonies along the southwestern and southern coasts and shells along the southern coast were buried in mud and debris which was washed down into the embayments by terrestrial waters.

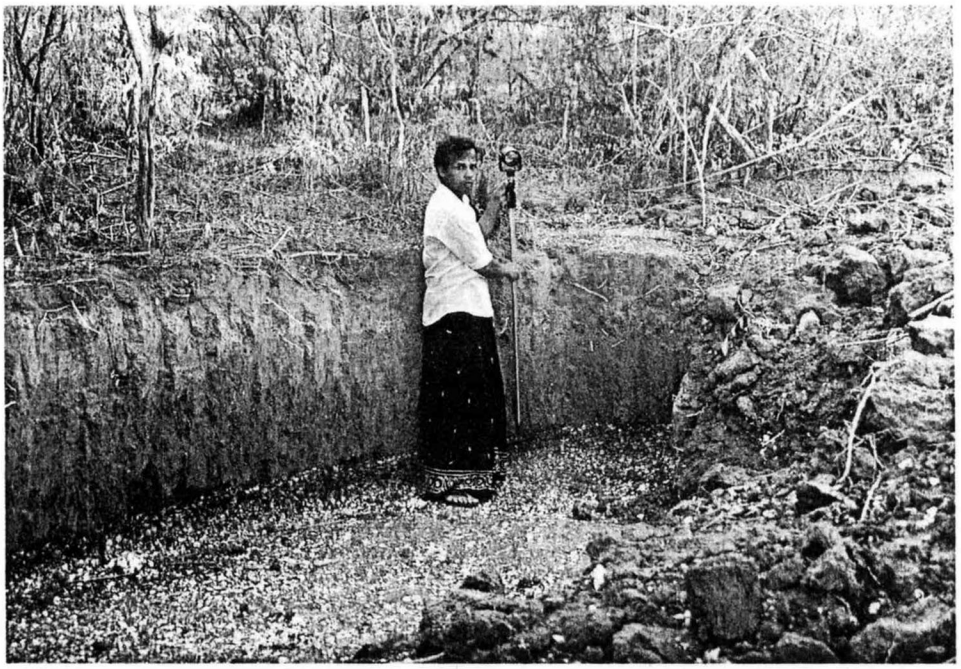


Plate 8. More than 1 m thick and fertile alluvial soil cover found on the thin shell bed at Bundala (Locations 17, 18 and 19).

Furthermore, the deposits had been intermittently covered by vast quantities of coral and/or shelly sand and various types of debris moved by severe monsoon waves. This is shown in Miniethiliya, Hatagala, Bataata-Gurupokuna, Kalametiya, Hunukotumulla, Nelumpathvila, Nabadewa and around Malala Lewaya areas. The colour and constituents of the layers show that they are subjected to local weathering conditions. Thickness of the top soil covered by these means varies locally, sometimes more than 1 m thick alluvial soil underlain on the shell beds. The deposition sequences of some shell patches of the mounds at Udamalala and on dune deposits help to infer that the valves have been discarded by early inhabitants and animals.

CONCLUSIONS

Emerged Holocene shell beds along the southern coastal zone between Kalametiya Kalapuwa and Bundala Lewaya are marine in origin. The shells of these beds have been piled up together with stone artifacts, pieces of pottery, human bones

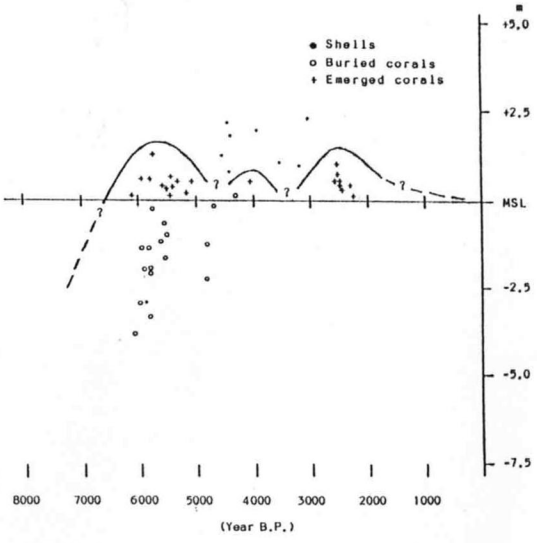


Figure 5. Mid- and Late Holocene high sea-level episodes in Sri Lanka (KATUPOTHA, 1992).

Table 2. *Dated shell beds along the Southern Coastal Zone.*

No.	Locality	Elevation (in metres)	AGe (yr B.P.) (half-life = 5,568 ± 30)	Laboratory No.	Deposition Process
1	Hungama	+1.3	5,780 ± 20	HR 12	Storm waves (SW)
2	Hungama	+0.8	4,440 ± 60	HR 264	*In situ*/SW
3	Kalametiya	+1.2	3,570 ± 60	HR 265	*In situ*?
4	Kalametiya	+2.2	4,460 ± 60	HR 266	Storm waves?
5	Kalametiya	+2.0	3,960 ± 60	HR 267	Storm waves
6	Karagan	+2.3	3,050 ± 100	HR 123	Shell midden
7	Udamalala	+6.5	4,050 ± 60	HR 122	Shell midden
8	Udamalala	+5.0	4,650 ± 70	HR 268	Shell midden

Source: KATUPOTHA (1988b, c)

and other animal bones by severe storm wave action on mounds, sand dunes and headlands, and in lagoon and lake bottoms. Bivalves of shells, in positions of growth, further indicate that the shell valves of lagoon, lake and channel beds (floors of marine and brackish pools) mostly accumulated as *in situ* as a consequence of the lowering of sea-level between 5,030–4,390 and 3,930–3,290 yr BP. The deposition sequences of some shell patches of the mounds at Udamalala and on dune deposits help to infer that the valves were discarded by early inhabitants and animals. The materials, stratigraphic sequence and different types of artifacts are valuable indicators in the study of the geological, archaeological and palaeoenvironmental significance of these beds.

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