

GEOLOGICAL SIGNIFICANCE OF MARINE MOLLUSKAN BEDS : EVIDENCE FROM SOUTHERN COASTAL ZONE OF SRI LANKA

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Abstract: Mollusks are invertebrate animals that live in brackishwater or marine habitats. The diversity and complexity of these habitats are due to winds, waves, tides, bottom features, daytime illumination, geologic origin of shoreline and ecologic conditions of the oceans. Assembly of bivalve and univalve mollusks occur due to the eustatic changes and the prevalence of coastal hazards. Stratigraphic sequences of shell beds along the southern coast between Kalametiya Kalapuwa (lagoon) and Bundala Lewaya (salt pan) clearly indicate that shells have been piled up together with stone artifacts, pieces of pottery, human bones and other animal bones. These were caused by severe storm wave action on mounds in lagoon and lake bottoms, on sand dunes and headlands. The present study shows that the shell valves of lagoon, lake and channel beds (floors of marine and brackish pools) mostly accumulated *in situ* consequent to the lowering of sea level between 5030 - 4390 and 3930 - 3290y B.P.

Key words: Marine molluscs, shell beds, south coast

INTRODUCTION

Assemblance of bivalve and univalve mollusks occur due to eustatic changes and coastal hazards. They are used as a geoscientific tool to study former sea-level stands.¹ Radiometric dating of the shells in different levels and quantitative analysis of their deposition sequences are helpful for this purpose. The present study attempts to reveal the geological significance of inland marine shell beds on the southern coast of Sri Lanka at a site between Kalametiya Kalapuwa and Bundala Lewaya in the dry zone (Fig. 1). The geological significance, extension and evolution of these shell beds have not previously been investigated.

METHODS AND MATERIALS

Extension of the shell beds was mapped based on detailed field investigations. From twenty locations, shell and soil samples were collected for geologic analysis between March and December 1992. Each sample contained 1.5 - 2.0 kilogram of shell and shell debris. All locations and sample heights were leveled to mean sea-level (msl) using TC 1600 EDM (Electronic Distance Measurement) theodolite (Set 3 B Sokkia) by a government licensed surveyor.

Separation of the grain sizes of the soil samples was undertaken using a BS 410, Laboratory Test Sieve (Endecotts, London). Before separation of grain sizes, weighted amount of dried soil (125 - 150g) was treated with 20% HCl to remove carbonates. The treated wet sample was dried in an oven at about 100°C for at least eight hours. Approximately 500 - 600g shells were also cleaned by

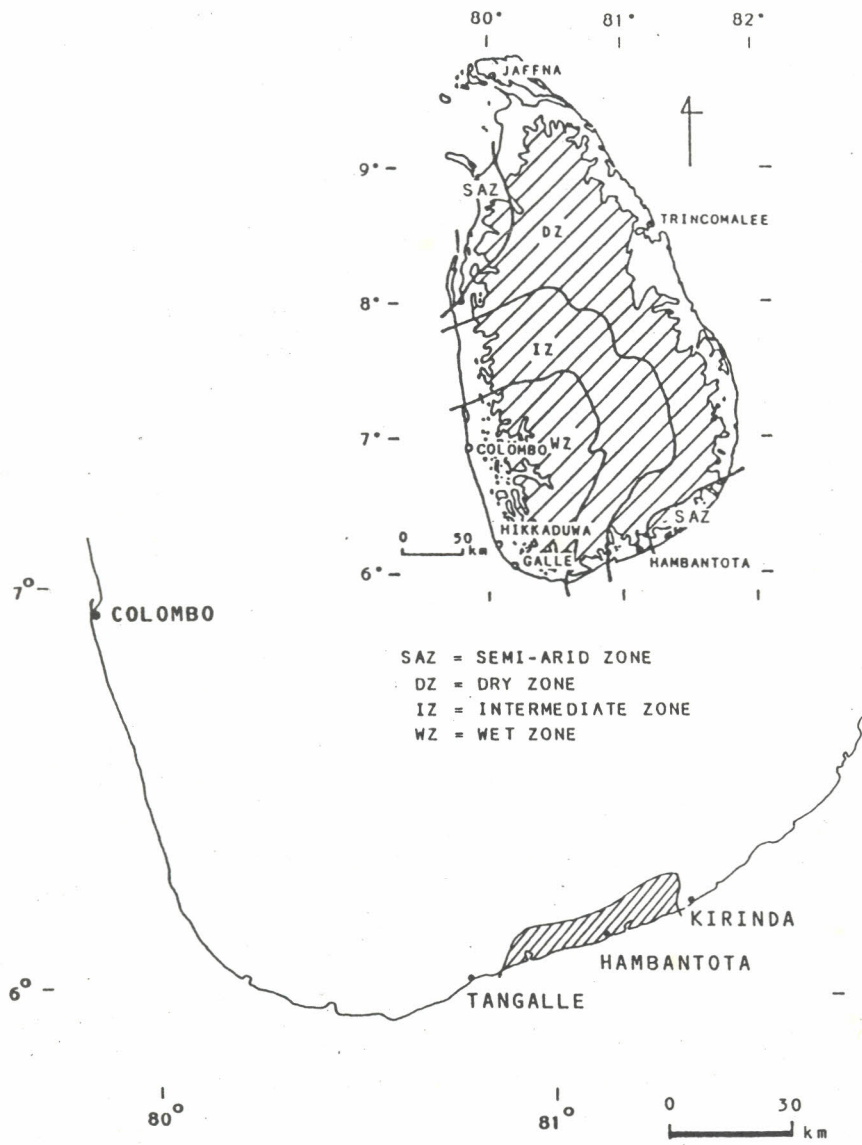


Figure 1: Location map of the shell bed areas along the southern coastal zone of Sri Lanka.

treating with 10% HCl for identification of the shells, and about 100g were preserved for future radiometric dating. Colour of the soil samples and shell embedded soils was determined using the revised standard soil colour charts.² The profiles of the shell layers were drawn using Harvard graphics. The laboratory work was conducted in the Department of Geography, University of Sri Jayewardenepura. Shells were identified with the help of a published catalogue.^{2,4}

Physical setting of the study area

The study area, is situated between longitude $80^{\circ}48' - 81^{\circ}16'$ and latitude $6^{\circ}03' - 6^{\circ}09'$ Ambalangoda and Hambantota topographic sheets (1:63,360) between Kalametiya Kalapuwa and Bundala Lewaya (Fig. 2 from a to k). Geologically the study area is underlain by the Highland complex rocks (undifferentiated rocks) on the western bank of the Walawe ganga, while the eastern bank lies on the Vijayan complex rocks (charnockite and charnockitic gneiss) of precambrian rocks.⁶ According to a Canada - Ceylon Colombo Plan Project (Resource of the Walawe Ganga basin⁷) the study sites consist of two types of rocks: (1) hornblende and biotite gneiss with associated pegmatite and migmatite (Vijayan complex rocks). (2) quartzofeldspathic gneiss and granulite (Khondalite series rocks). 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 both Highland and Vijayan complex rocks. Broadly, the study area can be divided into three geomorphic units based on elevation and the composition of the deposits⁸ namely: (1) flat terrain (lowland I, <30 m, slope is $1/2^{\circ}$ or 1° (60:1 or 100:1 in gradient). (2) flat to slightly undulating terrain (lowland II, <30 m). It has 1° to 3° slope or 60:1 to 20:1 gradient and can be designated as 'flood plain'. (3) undulating terrain (lowland III, 30-150 m). Slightly undulating, undulating and rolling features appear particularly in the area between Udawalawe and Ridiyagama.

The shell beds are mainly concentrated in the flat terrain (lowland I) beyond the western and eastern sides of the Walawe ganga. The coastal belt which included lowland I has been altered by terrestrial, aeolian and marine processes, and has formed narrow and long beaches, beach ridges with medium (3 - 5 m) and somewhat high (8 - 12 m) dunes. Sand spits are common features at the estuaries of the Walawe ganga and lagoons. Salterns, salt marshes and mangrove swamps and mound topography (a hummock relief) lie behind them. Too small and low bedrock outcrops appear as erosional remnants. The stony gravel beds and alluvium are the terrestrial deposits transported from upland and mountainous terrains.⁸

According to Köppen classification,⁹ the southern coastal zone, from Matara to Bundala is included into 'Afwi', 'Amwi' and 'Asi' climates. Distribution of rainfall of the Hambantota meteorological station shows two maximum seasons (Fig. 3) during the southwest monsoon (May to September) and convectional-cyclonic-depression (October to November).

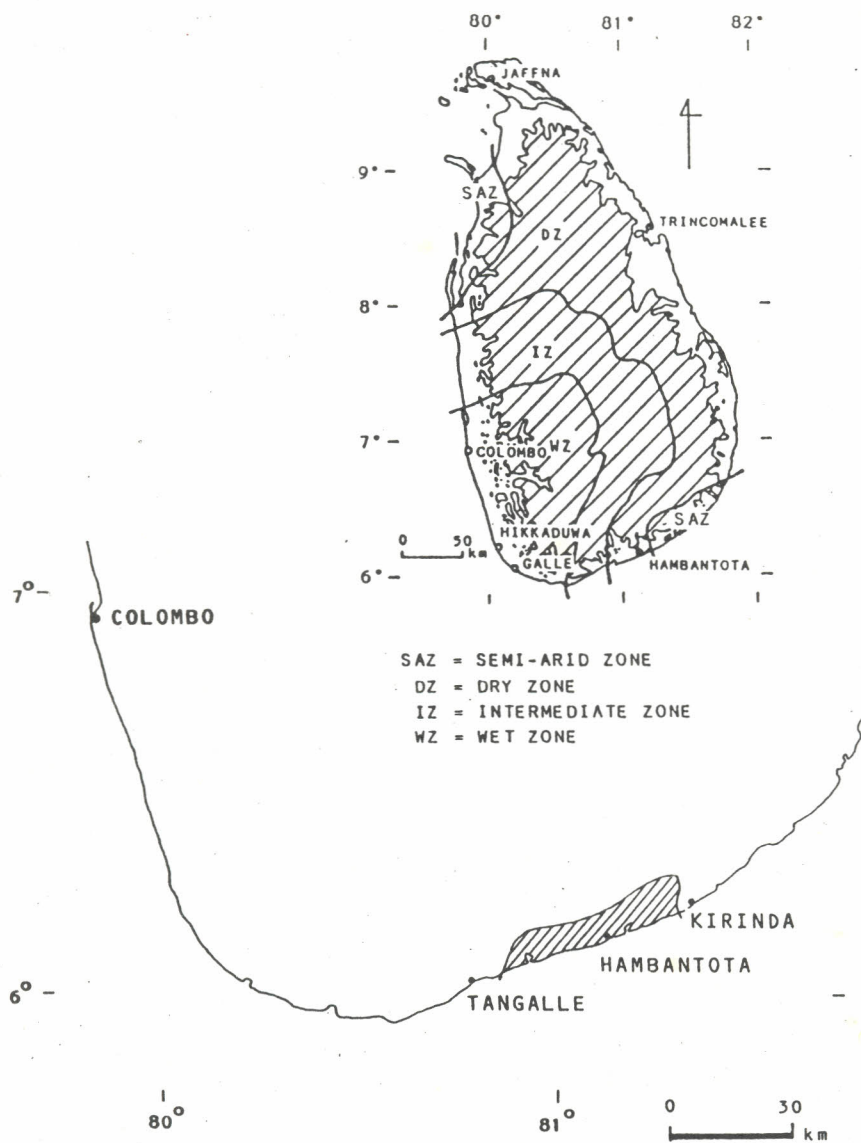


Figure 1: Location map of the shell bed areas along the southern coastal zone of Sri Lanka.

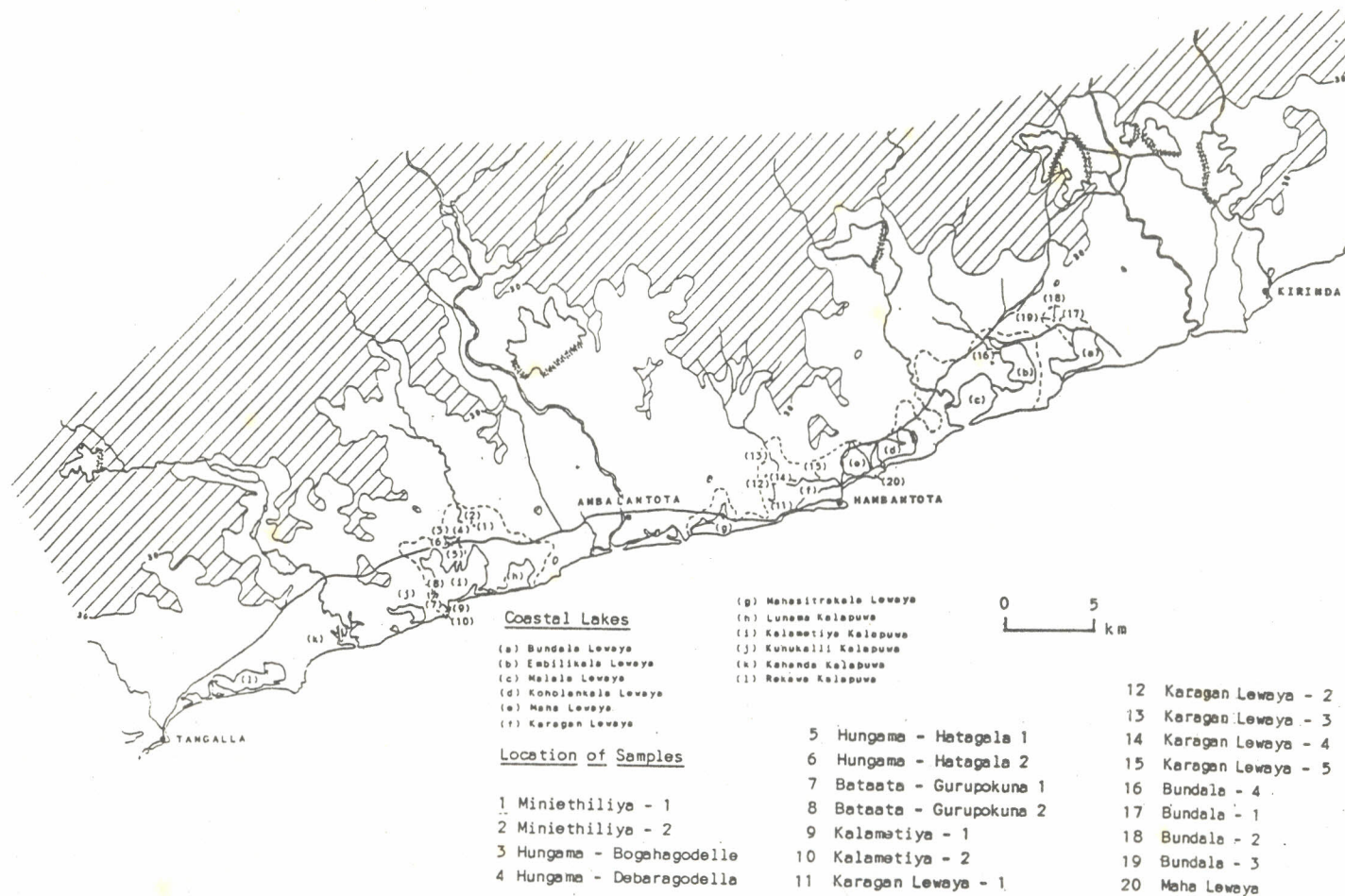


Figure 2: Extension of marine shell beds along the southern coastal zone.

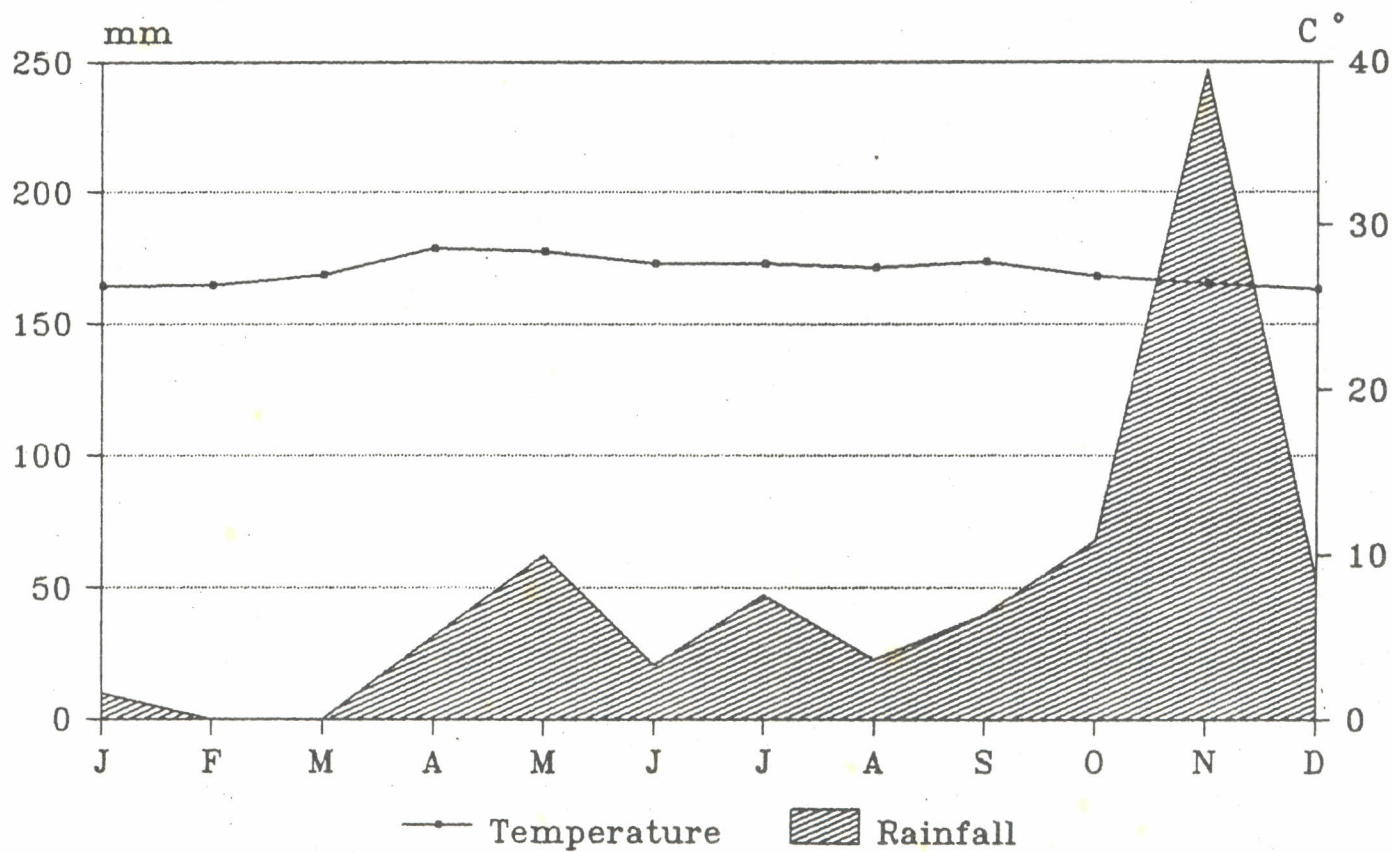


Figure 3: Monthly variations of the temperature and rainfall at Hambantota meteorological station in 1989.

The soils of the study area have a close relationship with geologic characteristics, microrelief and the seasonal distribution of rainfall. Four main soil groups¹⁰ of the study area have been identified as follows: (1) reddish brown earths with high amount of gravel in subsoil & low humic clay soils (2) reddish brown earths & solodized solonetz (both (a) and (b) types lie on the undulating terrain) (3) alluvial soils of variable drainage and texture (flat valley bottoms, water logged areas etc. covered by these soils) (4) regosols on recent beach and dune sand. Barrier beaches, beach ridges, sand spits and dunes along the coast are formed by such materials. Rocknob plains and erosional remnants in the coastal plain are formed by granitic gneiss, quartzite, hornblende gneiss and hornblende - biotite gneissic rocks.

The coastal lowlands are covered by barren lands mainly sand dunes. Most of the dunes are covered by creeping vegetation (*Spinifex littoreus*; *S-maharawana reula* and *Ipomoea pescaprae*; *S-mudubintamru*) and scrublands. 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 brackishwater lakes of the area are subjected to daily tidal fluctuations. *Sonneratia alba* (S-kililla) is the dominant mangrove species of the area. Among other important mangroves are *Nypa fruticans* (S-ginpol), which extends along edges of lagoons and tidal creeks, *Rhizophora* (S-kadol), *Bruguiera* (S-sirikanda) and *Ceriops* (S-kaduru) spp. Lowlands which are slightly above the mean high water springs level appear as freshwater marshes. Brackishwater and freshwater marshes are widely occupied by *Typha angustifolia* (S-hambupan) along the lower part of the Walawe basin.¹¹

The undulating low ridge and valley topography (30- 150 m), behind the coastal lowlands are covered by dry zone thorny forest and sparsely used croplands, homesteads and chena cultivation. The paddy lands have been concentrated in the fairly wide valley bottoms toward the inland from the coast.

Marine mollusks as a sea-level indicator

Sea-level indicators such as raised marine deposits, coastal barrier sands, beachrock, ooids, corals and reefs, coralline algae, marine notches, submerged forests marine mollusks etc. 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.¹²

Mollusks are a group invertebrates that are terrestrial, brackishwater or marine in habitat. The diversity and complexity of their habitats are due to winds, waves, tides, bottom features, daytime illumination, geologic origin of shoreline and ecologic conditions of the oceans and create special zones (Fig. 4) for different shell species.^{2,3,13} The basic nature of the mollusks was determined millions of years ago as the great land continents were drifting into their present position. As the climate (atmospheric and oceanic), changed and vacillated, all species came under new challenges to their survival.¹² The least adaptable are

found today only as fossil remnants locked in tertiary beds; other populations were divided; isolated and changed into new species, while more resistant ones flourished and spread from terrestrial to pelagic areas. The phylum Mollusca contains six classes viz; Monoplacophora, Amphineura, Gastropoda, Scaphopoda, Bivalvia and Cephalopoda. 'Habe' states that seven classes of mollusks including Aplacophora with the above six are composed of 112,000 species.

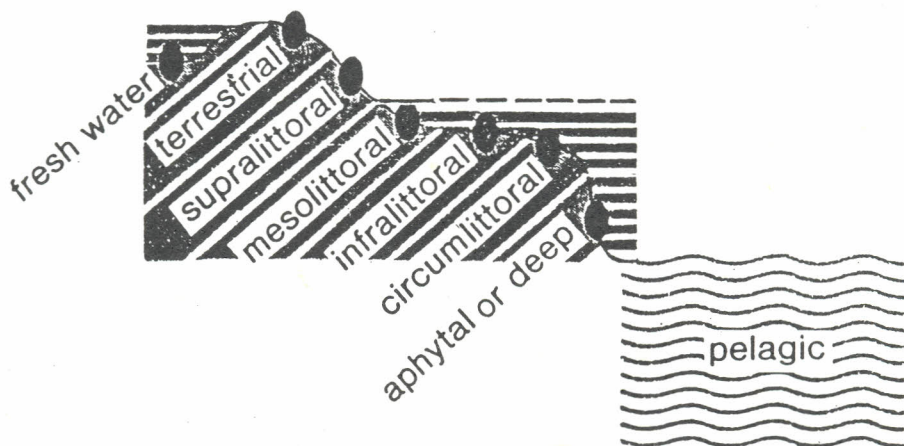


Figure 4: Extension of marine molluskan zones between supralittoral and circumlittoral.

Aplacophora dates from the Lower Cambrian; the class has 10 species. The worm-shaped creatures have no shells. The Monoplacophora (Neopilina Class) well-known from the Palaeozoic deposits of epicontinental seas, are today only represented by those recently found from the deep sea, having a limpet-like (cap-shaped) shell. Scaphopoda (tusk shells), tube shaped shells which widen towards the aperture, are known from the Devonian period. The Bivalvia (Pelecypoda) are mainly found in areas close to the coast. The clams are covered with two shells. They are known from the lower Devonian. The Gastropoda are the most varied group within the molluska. They date from the Upper Cambrian. Cephalopoda (Squid and Octopus Class) are all predatory, swimming carnivores occurring in the major marine habitats. The Amphineura (Polyplacophora - Chiton Class) are found from temperate to tropical areas and they usually live on rocky surfaces close to the shore. These date from the Ordovician to the present. These mollusks inhabit all the different regions of the sea, from cold polar regions to the warm equatorial belt, from surface water and intertidal beaches down to abyssal depths, but the warm shallow seas where reefs and rocks abound are thickly populated.

The continental shelf around Sri Lanka comprises of submerged rocks, sand banks, sandstone and coral reefs. Most of these features are situated on the mesolittoral zone, known also as the intertidal zone (it extends from the high-tide mark to the normal low-tide mark). Intralittoral plane extends from the lower limit of the mesolittoral to the lowest depths at which a certain family of plants occur. The seas around Sri Lanka provide an ideal environment for a rich variety of molluscan shells. Kirtisinghe¹³ has pointed out that research on sea shells of Sri Lanka occur sporadically in zoological journals and the records of oceanographic surveys. He described about 530 species collected in the seas around Sri Lanka.¹³ Many of these are also found throughout the Arabian sea southward to the east of Australia, and along the coast of Australia.

Three types of marine mollusks are found in Sri Lanka¹³: (1) Pelecypoda or bivalve mollusks (bivalvia by Peterson¹) (2) Gastropoda or snail-like mollusks and (3) Cephalopoda.

RESULTS AND DISCUSSION

Microrelief of Shell Beds

The extension of the whole shell beds along the southern coastal zone is laid in flat terrain, below 30 m. 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 swells.¹⁴ 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 outfalls of the Walawe Ganga and the circular shaped lagoons. 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, salt marshes and mangrove swamps behind them. The lagoon and lakes are known locally as 'lewayas' and these are not fed by large streams. Most of them are very saline due to the persistent winds and dry climate. These conditions have been created by rapid evaporation. Slight undulations of the area extend as lobes sloping towards the coast. Most of them appear as low outcrops along the coast.

Geological Significance of the Shell Beds

The shells were found to be concentrated in pockets around the Kalametiya kalapuwa, Hungama, Lumnama kalapuwa, Mahasittrakala lewaya, the area between Karagan lewaya, Pallemalala, Embilikala kalapuwa and Bundala lewaya. The extension of the shell beds is shown in Figure 2. *Meretrix* spp. are the dominant mollusks in the whole area. Beside this, *Anadara* spp. and *Cerithidea* spp. are also found mixed with *Meretrix* spp. or separately (Plate 1). Most of these are found in paddy fields, small mounds (hummocks), former embayments and the bottoms of lagoons, lakes and creeks. The shell beds at

Hatagala extend up to Miniethiliya about 4 kilometres inland from the present coast. The shell 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 (Fig. 5, Location No. 1; Fig. 6, Location No. 2) about 0.5 ha. in size. Calcareous clay with sandy (little) soil (Grayish Gray Soil - 10 YR 4/2) contain in the top layer. Tiny and small to somewhat large size of shells can be found. Shells belong to *Cerithidea* spp. (below 20 mm) and *Meretrix* spp. (below 40 mm in size). Elk bones (horn) together with *Meretrix* spp. were found in Location No. 2. Shell debris, sub-rounded quartzite pebbles, coarse to fine sand with clay and other animal remains are embedded in the deposits. Although the shell beds of the area are about 4 kilometres inland from the present coast, the thickness of the layer is considerably high. The beds at Hungama - Pallegama (Ihalagama Yaya) are also mixed with univalve shells, *Anadara* spp., *Meretrix* spp. pottery fragments and animal bones.

Similar features with very thick shell layers are found at Hatagala - Bogahagodella (Fig. 7, Location No. 3; Plate 3). Most of these shell mounds are covered by thorn bushes and stunted trees. Shells, shell rubble mixed with calcareous sand and clay (Light Gray - 10 YR 7/1) in sample 1. The shell of sample 2 in the same location is mixed with Brownish Gray soil (10 YR 4/1). A pure quartz pebble was found in this sample. Shells belong to *Cerithidea* spp. is below 20 mm and *Meretrix* spp. is also below 20 mm in size (Plate 3). The shell beds at Debaragodella (Fig. 8, Location No. 4). are mixed with calcareous clay (Brownish Gray soil (7.5 YR 4/1) in sample 1. There are no pebbles or coarse sand, but pure quartz fragments are found. Calcareous clay with fine sand and shells (grayish brown soil - 7.5 YR 4/2) were in sample 2. The clay was compact when dry. The clams in live position were also found in this sample.

A coconut land at Hatagala (temple land, about 0.25 ha. in size) has a considerable amount of shells (Fig. 9, location No. 5). Tiny and small size to large size of shell 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 of the mound has been mixed with stone pebbles (appear as artifacts), human bones, fragments of pottery etc. Highly weathered human skeletons were found at same mound of location No. 6 (Fig 10). A part of a jaw with teeth, vertebral columns, rib cages and radius are found in this location. The last teeth of the jaw indicate that the skull belonged to a young human. Other conditions of the site are very similar to location No. 5. 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 2b, 4 and 5c).

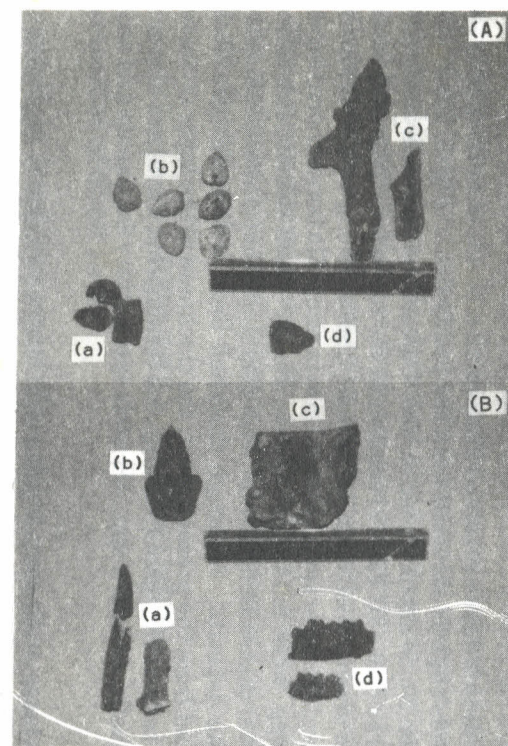
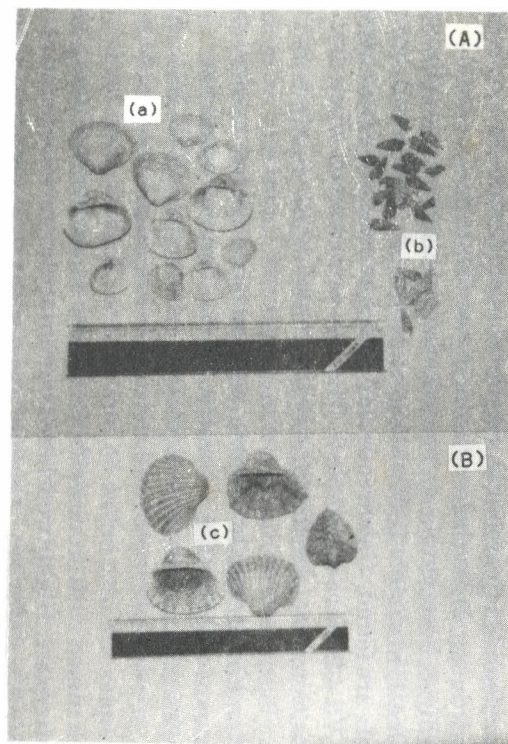


Plate 1: (A) *Meretrix* (a), *Cerithidae* (b); and (B) *Anadara* (c) spp. contained in the shell beds along the southern coastal zone.

Plate 2: (A) Fired quartzite pebbles (a) *Meretrix* shells in living position (b), elk bones (c) and pieces of pottery (d) from Hungama - Ovitigodayaya paddy field; (B) Pieces of elk bones (a) serpent's head (b) and human bones (c & d) at Location Nos. 5 & 6.

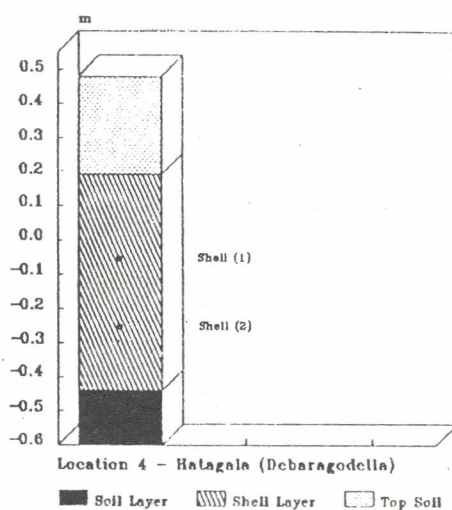
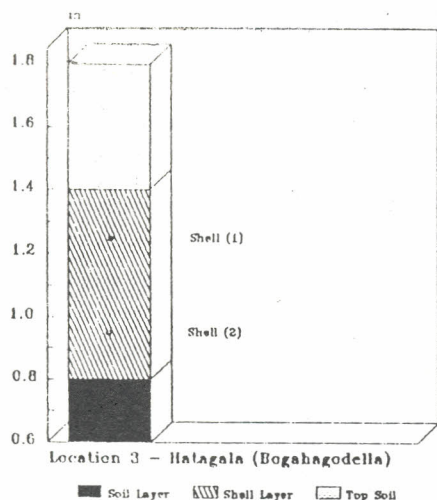
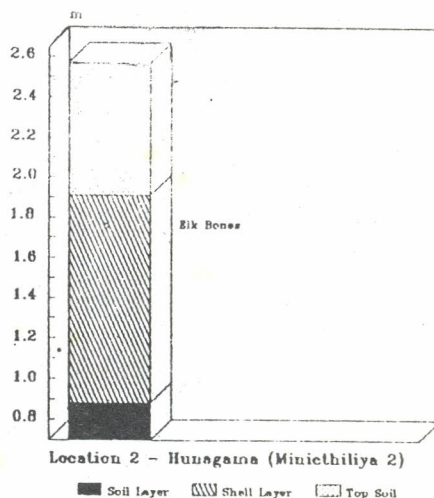
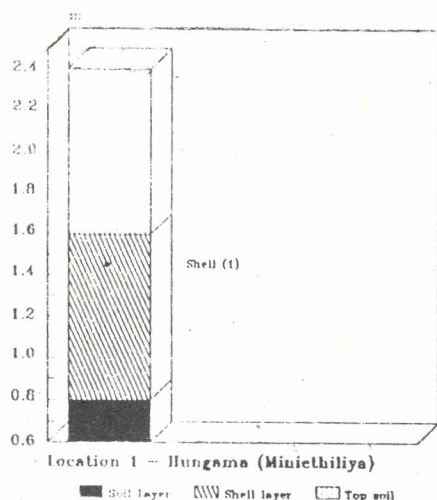


Figure 5, 6, 7 and 8: Stratigraphic sequences of the shell beds at location nos. 1,2 (Hungama - Miniethiliya), 3 (Hungama - Bogahagodella) and 4 (Hungama - Debaragodella).



Plate 3: About 1 m thick shell layers at Hungama - Bogahagodella (location No. 3).

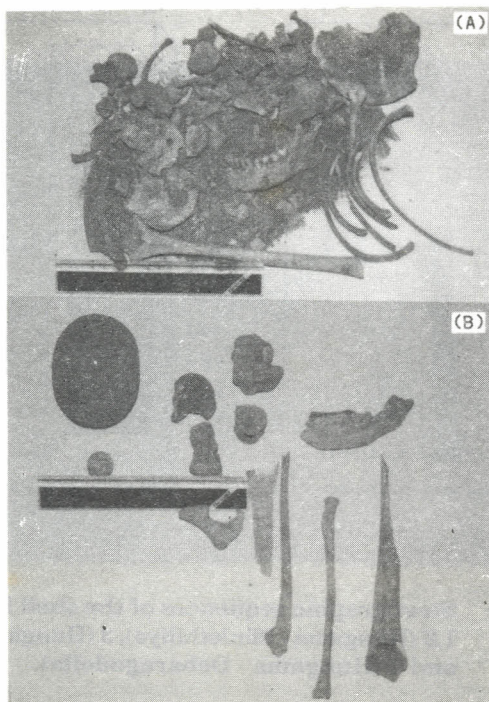


Plate 4: (A) Debris of human bones, (B) Human and other animal bones and stone artifacts from the shell beds at location no. 5 & 6.

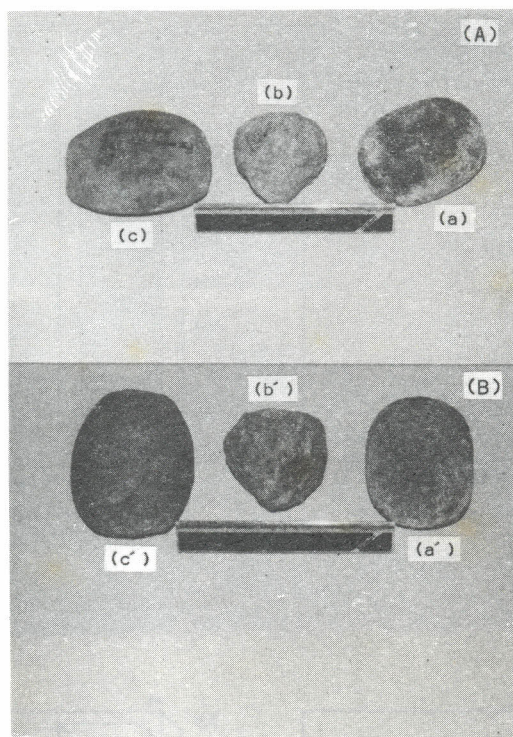


Plate 5: (A) Stone artifacts collected from the shell beds at location no.5 (c), Nabadewa (5b - same stone artefact of the Plate 9) and location no. 19 at Bungala (5a). (B) backside of the same stone artifacts (c', b' & a').

Two distinctive beds at Bataata - Gurupokuna and Kalametiya have been deposited in morphologically different areas. The beds at Gurupokuna 1 (Fig. 11, location No, 7 & Fig. 12, location No. 8) appear as about 3 m thick deposits (horizontally deposited) on mounds and a former lagoonal beach (Plate 6). Sample 1 belongs to light gray shelly sand (10 YR 7/1). Clear quartz fragments were in the sample. The size of the *Meretrix* spp. is below 35 mm and *Cerithidea* spp. is below 25 mm. Sample 2 contains light gray shelly sand (10 YR 7/1). The *Meretrix* spp. is small (below 30 mm) and *Cerithidea* spp. appear as fragments. Unidentified shell fragments are also found here. Sample 3 of this location is classified as dull yellowish orange soil (10 YR 6/3). *Meretrix* spp. (below 50 mm in size) and somewhat weathered *Cerithidea* spp. (below 20 mm in size) are found. Sample 1 of the location No. 8 is mainly composed of light gray sandy soil (10 YR 7/1). *Meretrix* spp. of the sample is below 40 in size. Sample 2 is formed by dull yellowish brown soil (10 YR 4/3), sand and shell rubble. *Cerithidea* spp. (below 20 mm). *Meretrix* spp. (below 40 mm) and *Anadara* spp. (below 45 mm) are the main shell types of this location.

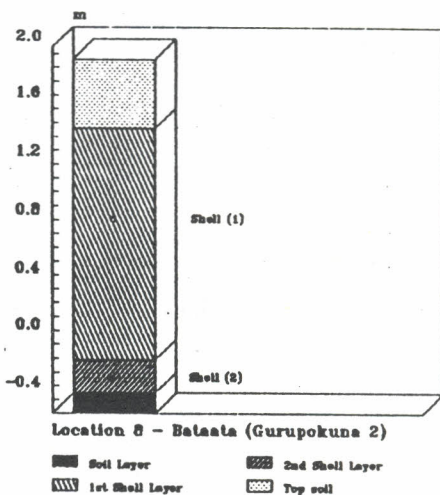
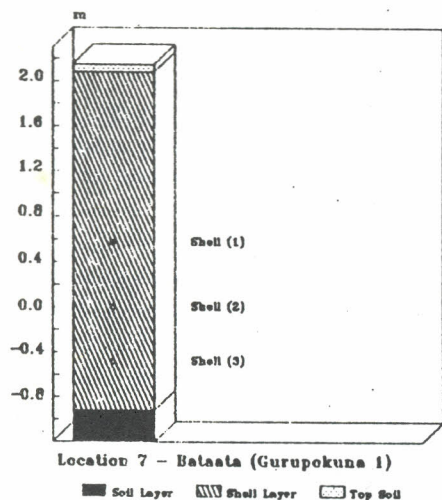
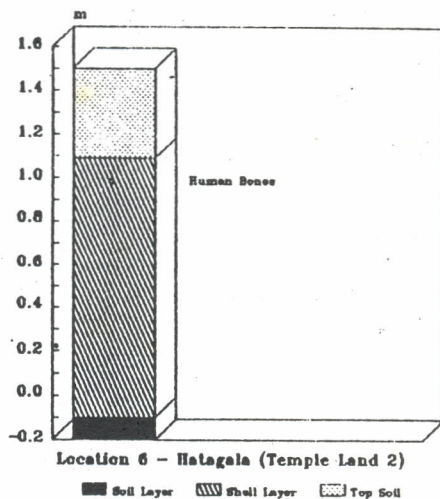
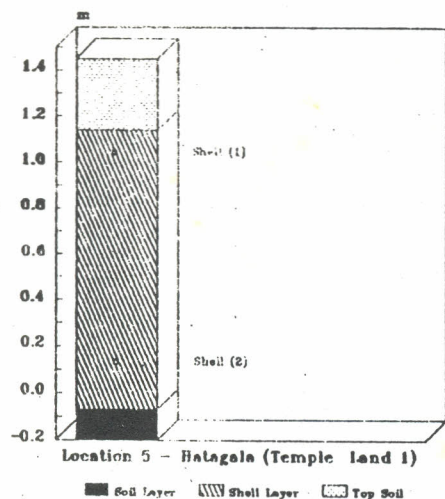


Figure 9, 10, 11 and 12: Stratigraphic sequences of the shell beds at Loc. Nos. 5, 6 (Hatagala - Temple Land), 7 (Bataata - Gurupokuna) and 8 (Bataata - Gurupokuna).

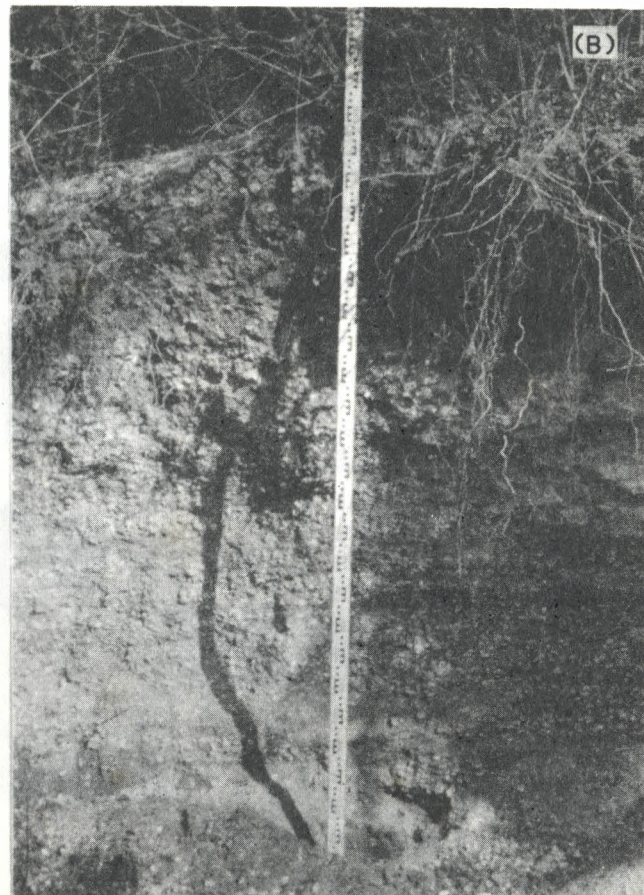
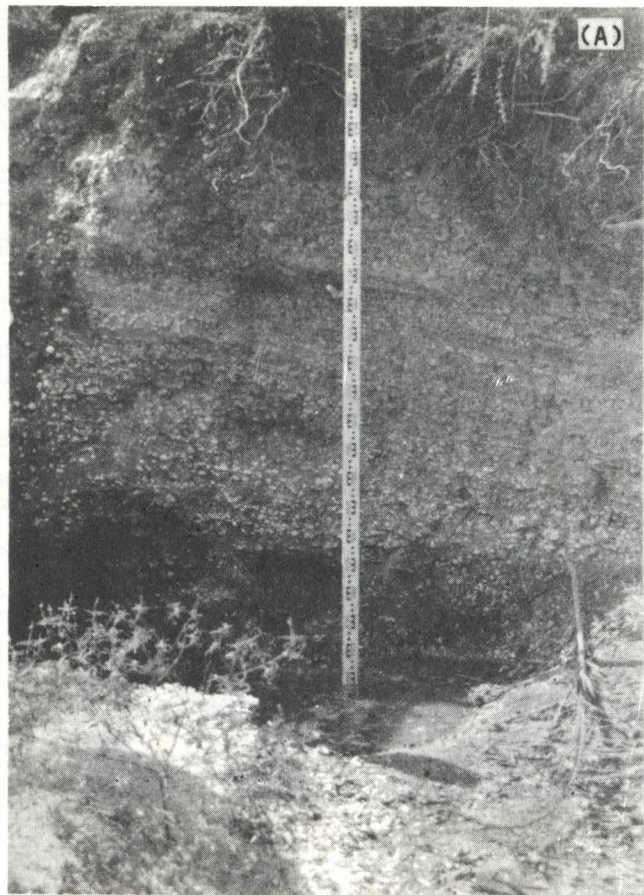


Plate 6: (A & B) Horizontal deposition patterns of the shell beds at Bataata - Gurupokuna indicate the shell valves have piled up by storm wave action (Loc. No. 7 & 8).

Kalametiya (Henagahapugala) beds (Fig. 13, Location No. 9) have been deposited on a rocky headland (with a thin soil cover) which is 13.8 m above mean sea level. The shells *Meretrix* spp. are below 40 in size. Broken large shells mixed together with brown soil (10 YR 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 strong wave action (Plate 7b). At location no. 10, brown fine sand with clay (10 YR 4/3) with shell and shell fragments appear in both shell samples (Fig. 14). The shells belong to *Meretrix* spp. (below 40 mm in size other comments are same as location no. 9). Inorganic content and grain sizes of the soil sample (10.1) are shown in Figure 17. Many pieces of pottery are mixed with the shell bed in this area (Plate 7a). The thickness and the height of the shell beds at Kalametiya (location nos. 9 & 10) are different to the other locations (Table 1). Eleven shell bearing micro-layers can be identified at Kalametiya, on a former lagoon, and contain *Meretrix* and *Cerithidea* spp. This sample point is not levelled due to the physical obstacles (Fig. 18, Plates 7b and 8).

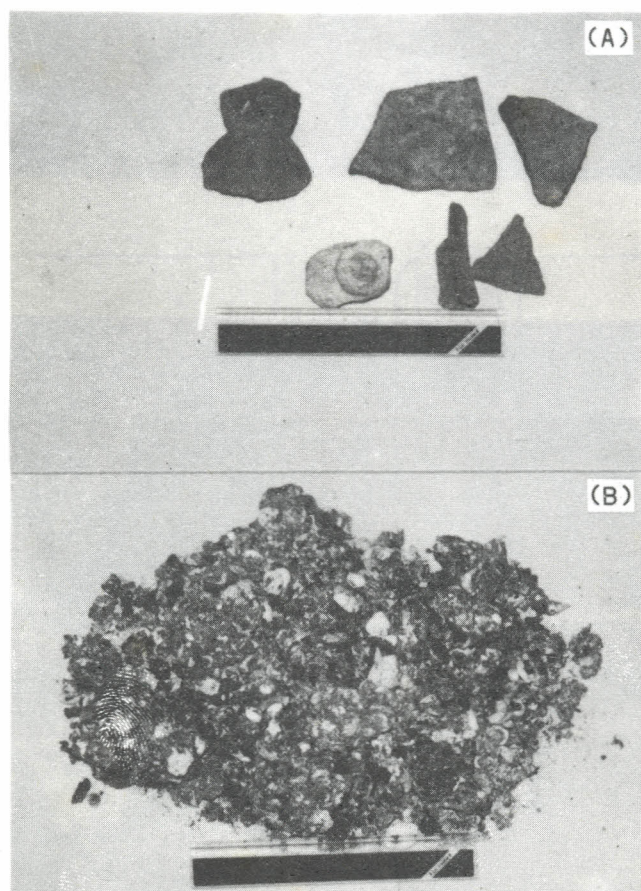
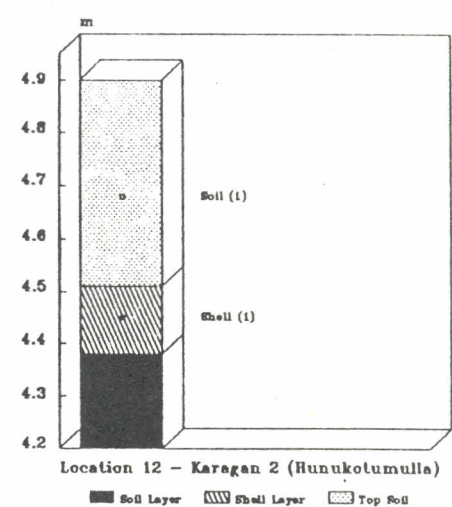
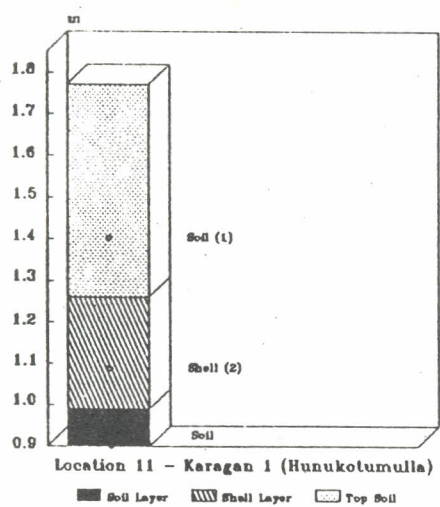
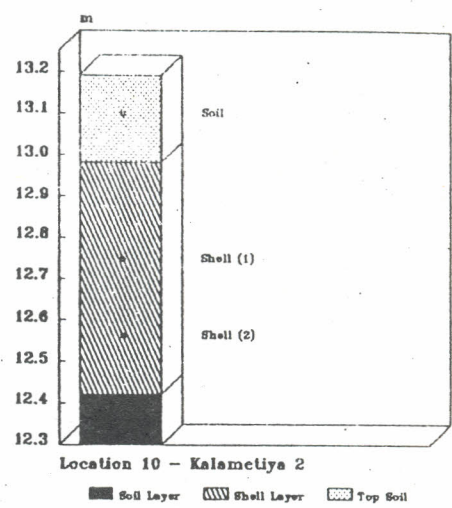
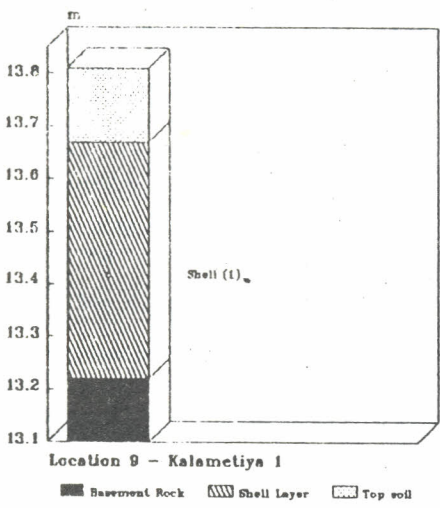
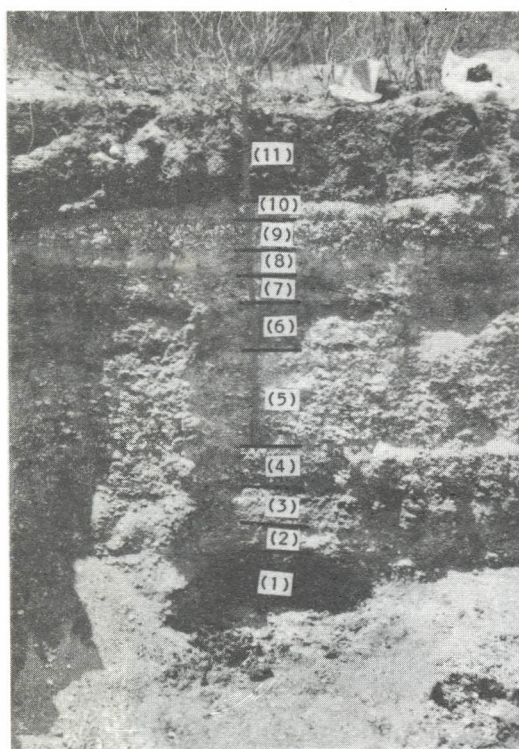


Plate 7: (A) Pieces of different types of pottery are found from the shell beds at Kalametiya (Loc. No. 9 & 10). (B) Peaty-clay with shells contained in the last series of the separate pit Kalametiya (Plate 8).



Figures 13, 14, 15 and 16: Stratigraphic sequences of the shell beds at location nos. 9, 10 (Kalametiya 1 and 2), 11 and 12 (Karagan 1 and 2).



- 1 = Bluish clay
- 2 = Shell and shell fragments mixed with few organic matter and calcareous clay
- 3 = Shell and shell fragments mixed with more organic matter and calcareous clay
- 4 = Shell composed of different kinds of shell fragments
- 5 = Shell mixed with sand
- 6 = Yellowish weathered shell fragments
- 7 = Shell with plenty of shell fragments
- 8 = Grayish sand
- 9 = Shell layer
- 10 = Shell and shell fragments
- 11 = Brown and gray soil

Plate 8: Stratigraphic sequences of the shell bed at Kalametiya. Eleven micro-layers (series) are identified based on the type and size of shells and constituents of other materials.

The shells from Godawaya to Mirijjawela are deposited as small pockets in depressions (lagoon and lake bottoms) between sandy beach and undulating terrain which gradually increase in altitude inland. The beds at Kiula Kalapuwa 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 (10 YR 4/3). The soil layer which is below the shell layer contains medium to fine brown soil (10 YR 4/4).

Somewhat large shell beds are found at Hunukotumulla on former lagoon beaches as well as lagoon bottoms of the western bank of the Karagan Lewaya (Fig. 15, location no. 11), these can presently be seen as mounds. They are also covered by thorny bushes, stunted trees and grass. Sample 1 in this location is formed of 7.5 YR 4/2 grayish brown medium to fine sand clay soil. The compact layer has weathered pebbles of iron. Grain sizes and content of inorganic matter of the sample 1 (11.1) are shown in Fig. 19. The shells have mixed with grayish

brown soil (7.5 YR 4/2). *Meretrix* spp. are below 40 mm in size. Three shells are found in position of life (30 mm below in size). Somewhat compact, soil in sample 3 is grayish yellow brown (10 YR 4/2) in colour). Calcareous clay patches and weathered ironstone pebbles are found. Grain sizes and content of inorganic matter of the soil sample (11.3) are shown in Figure 19. Some beds, at the Location No. 12 (Fig. 16) have deposited by wave action. The shells mix with Brown soil (7.5 YR 4/3) and fine sand and calcareous materials. Pebbles are very few. Plant remains are evident. *Meretrix* spp. (below 45 mm) and *Anadara* spp. (below 65 mm) are main shell types of the area. Grain sizes and inorganic content of the soil sample (12.1) are shown in Fig. 17.

The shell pockets in the northwestern area of the Karagan Lewaya (Fig. 20, location no. 13), Nelumpathvila compose of dull yellowish brown soil (10 YR 5/4) with fine sandy clay and shelly sand. *Meretrix* spp. of the sample is varied from small to somewhat large (below 40 mm). The shell layer at location no. 14 - Karagan 4 (Nelumpathvila) composed of dull yellowish brown soil (10 YR 5/4) with fine sandy clay and shelly sand (Fig. 21). Somewhat large *Meretrix* spp. are below 40 mm. Sample 1 at the location no. 15 - Karagan 5 (Nelumpathvila) also contains brownish gray soil (10 YR 6/1) with calcareous sand and clay (Fig. 22). The shell layer is composed of dull yellowish brown soil (10 YR 5/4) with fine sandy clay and shelly sand. *Meretrix* spp. of the sample is somewhat large (below 40 mm).

Extensive shell beds at Sippikulana, around the Maha lewaya and Koholankala (Koholankala lewaya) are found on slight undulations (lobes). The shell layers here are thin compared to the beds at Gurupokuna, Hungama and the Karagan lewaya (Table 1). Furthermore, many shell patches are found in the area between Maha Lewaya and the Nabadewa, Pallemulla area, on the eastern bank of the Malala oya (Plates 5b and 9). These shell beds are composed of stone artifacts and quartzite pebbles. Based on the colour of the quartzite pebbles, it is possible to infer that these may have been fired. Some beds are more than 4 km inland from the present coast.

A considerable amount of shell beds are found in the area between Malala lewaya and Embilikala kalapuwa (around Pallemalala, location no.16). These beds also appear on mounds and ditches of the area covered by scrublands and stunted trees. The shells at this location contain grayish brown soil (7.5 YR 4/2) with fine sand and clay, weathered pebbles, quartz fragments, plant remains. *Meretrix* spp. is below 45 mm and weathered *Cerithidea* spp. appear as fragments (Fig. 23).

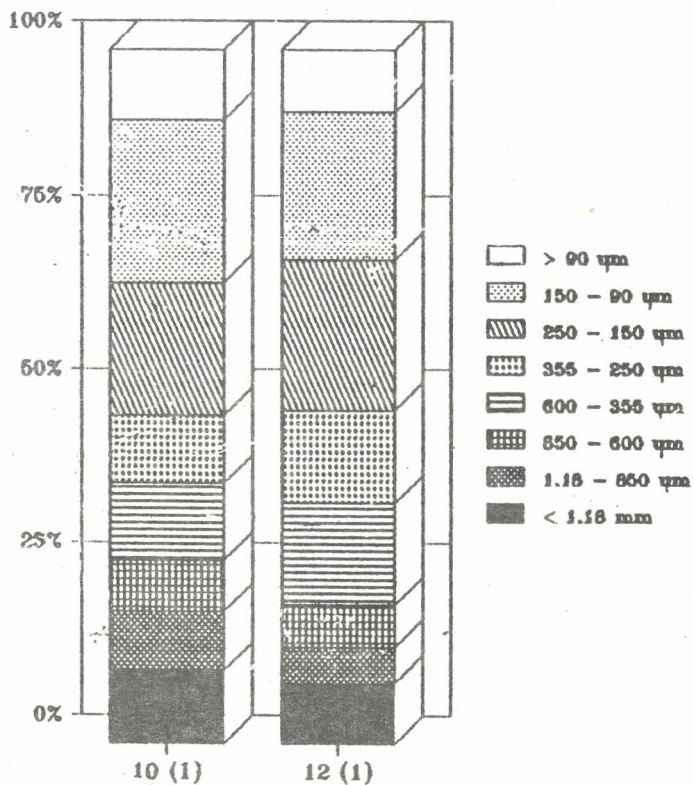
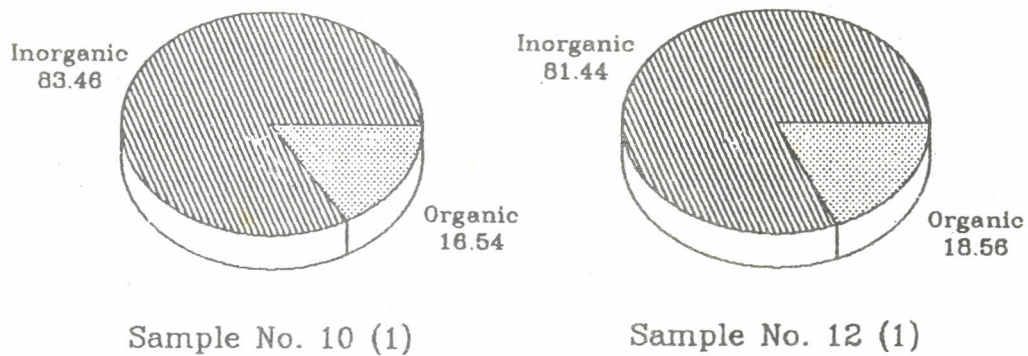


Figure 17: Inorganic contents and grain size analysis of the soil samples 10.1 and 12.1.



Plate 9: Glossy and well preserved shells and stone artifacts (quartzite) foundat Nagadewa, left bank of the Malala Area, about 4 km inland from the present coastline. Thick fertile alluvial soils overlain on the shell beds.

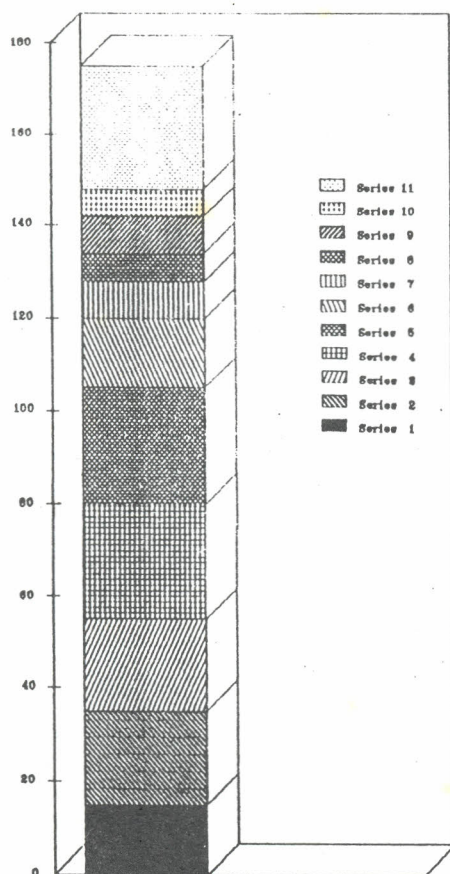


Figure 18: Stratigraphic sequences of the shell bed at Kalametiya.

Extensive shell beds are found in many mounds along the northern beach of Embilikala kalapuwa and on the side left of the Bundala road. The shell beds around Bundala lewaya are somewhat high and thick (Table 1) compared to the shell beds at Maha lewaya and Embilikala kalapuwa (location nos. 17, 18 & 19). Dark Brown medium sand to fine sand with clay soil (7.5 YR 3/3) appear at the location no. 17 - Bundala road 1 (near 4th km). The soil is somewhat compact. Plant roots and other organic matter are found. Damaged *Meretrix* spp. found here are below 30 mm in size. Weathered *Cerithidea* spp. found here are below 20 mm in size (Fig 24). Dark Brown medium sand to fine sand with clay soil (7.5 YR 3/3) of samples 1 & 2 in location no. 18 - Bundala road 2 (near 4th km) is somewhat compact. Plant roots with other organic matter are found (Fig. 25). The shells (sample 3) have deposited with grayish brown soil (7.5 YR 4/2), medium to fine sand, calcareous, clay and feldspar pebbles (rare). *Meretrix* spp. found here are below 30 mm and weathered *Cerithidea* spp. are below 20 mm in size. Grain sizes and content of inorganic matter are shown in Figures 28(18.1) and (18.2).

Table 1: Details of the Raised Shell Beds on the Southern Coast

No	Location	Lower level of the shell layer (metres)	Ground level (metres)	Thickness of the shell layers (metres)	Relief
1	Miniethiliya 1	0.80	2.40	0.80	mound
2	Miniethiliya 2	0.87	2.56	1.03	mound
3	Hungama - Bogahagodella	0.80	1.80	0.60	mound
4	Hungama - Debaragodella	-0.44	0.48	1.21	mound
5	Hungama - Hatagala				
	Temple Land 1	-0.06	1.45	1.21	mound
6	Hungama - Hatagala				
	Temple Land 2	-0.10	1.50	1.18	mound
7	Bataata - Gurupokuna	-0.90	1.50	3.00	rocky mound
8	Bataata - Gurupokuna	-0.50	1.90		rocky mound
9	Kalametiya 1	13.25	13.80	0.45	headland
10	Kalametiya 2	12.40	13.20	0.60	headland
11	Karagan Lewaya 1	1.00	4.90	0.25	lag. coast
12	Karagan Lewaya 2	4.38	2.50	0.12	mound
13	Karagan Lewaya 3	1.30	2.50	0.40	lag. coast
14	Karagan Lewaya 4	1.54	1.50	0.56	lag. coast
15	Karagan Lewaya 5	1.00		0.20	lag. coast
16	Bundala - Embilikala	3.20	3.90	0.30	mound
17	Bundala Road 1	8.60	9.70	0.70	mound
18	Bundala Road 2	8.60	9.75	0.18	mound
19	Bundala Road 3	9.17	10.20	0.16	mound
20	Maha Lewaya	3.08	3.65	0.17	lag. coast

Source: Field Survey

Stratigraphic conditions, types of shells and the soils of the location no. 19 are as same as locations 17 and 18 (Fig. 26 and Plate 5b). Shells mix with dull yellowish brown soil (10 YR 4/3) at the location no. 20 - Maha Lewaya (Koholankala) with calcareous clay. Well preserved *Meretrix* spp. of the sample is below 35 mm in size (Fig. 27). They are also deposited on former lagoon beaches. The top soil (alluvial) cover of the Bundala area is about 1.5 m thick. In location No. 20 at Maha Lewaya (Koholankala) the shells are mixed with dull yellowish brown soil (10 YR 4/3) with calcareous clay. Well preserved *Meretrix* spp. of the sample here are below 35 mm in size. Present extension of the shell beds indicated that they have been deposited on mounds, along the lagoon and lake beaches as well as in lagoon and lake bottoms. Most of the beds are presently covered by superficial deposits (alluvium and wind blown sand).

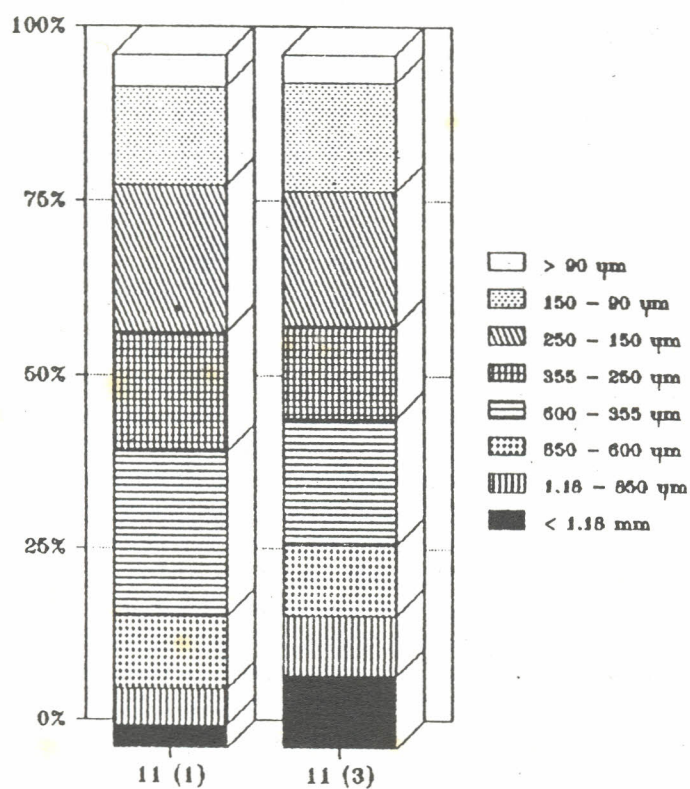
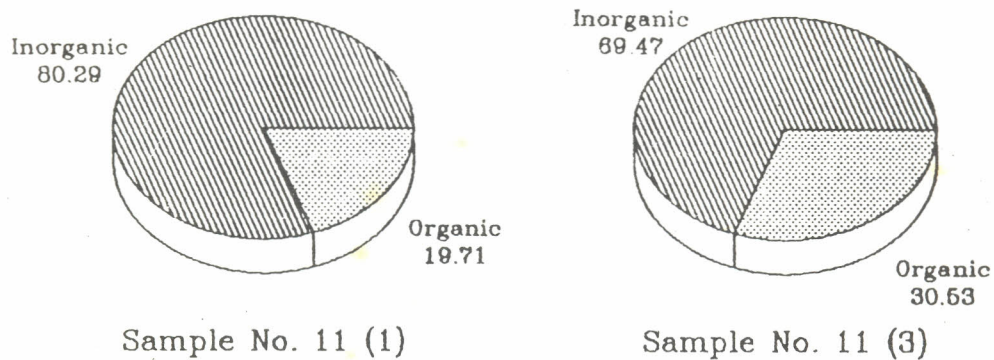
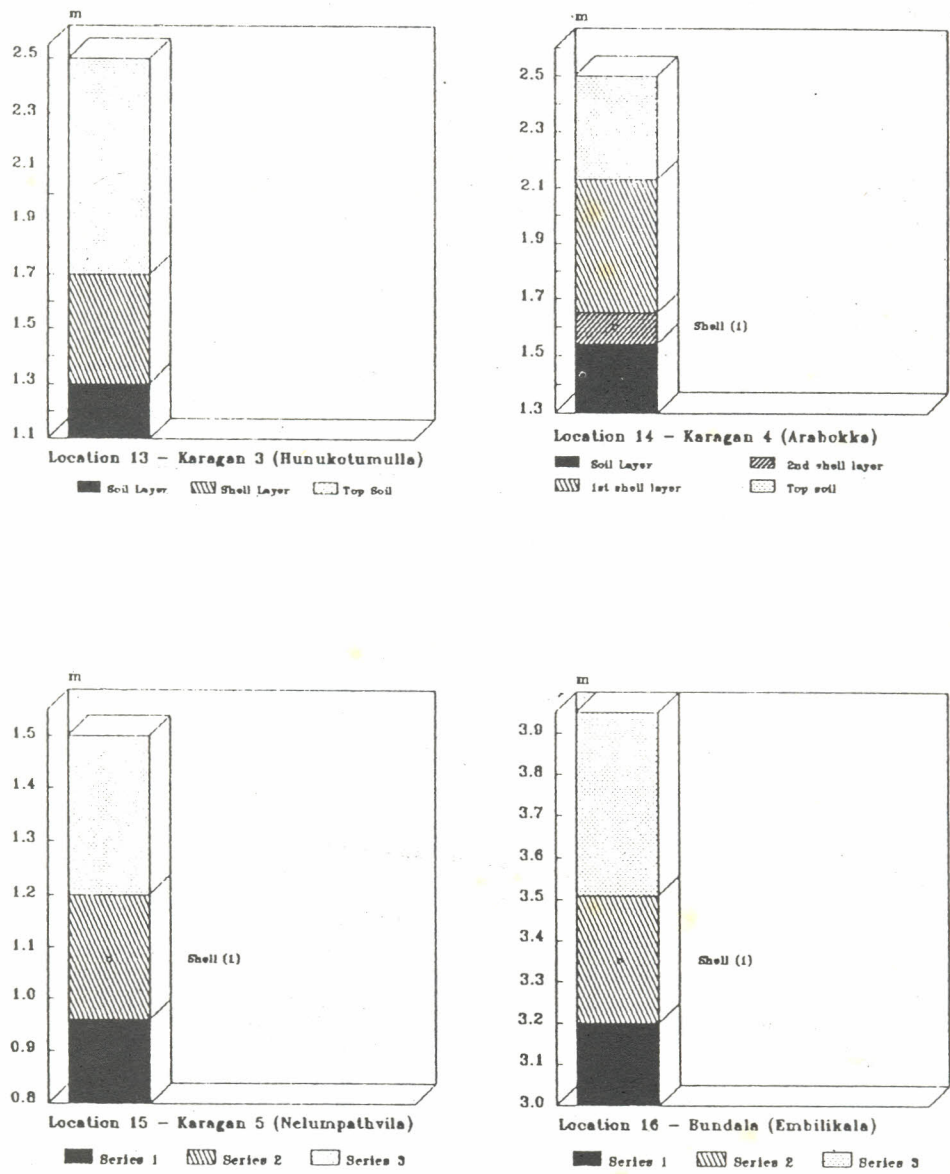
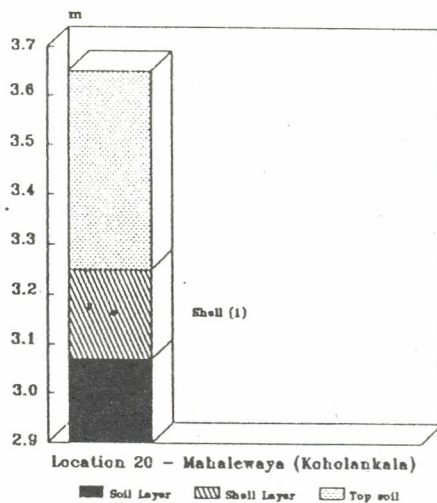
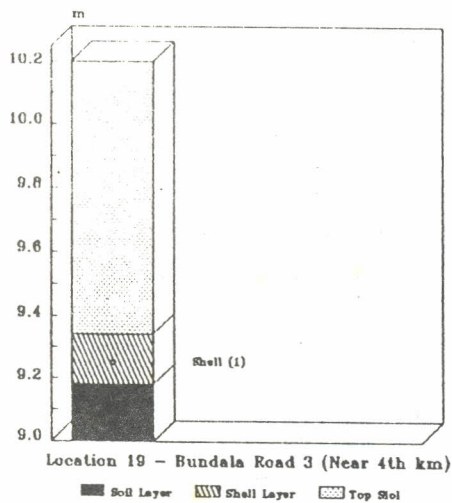
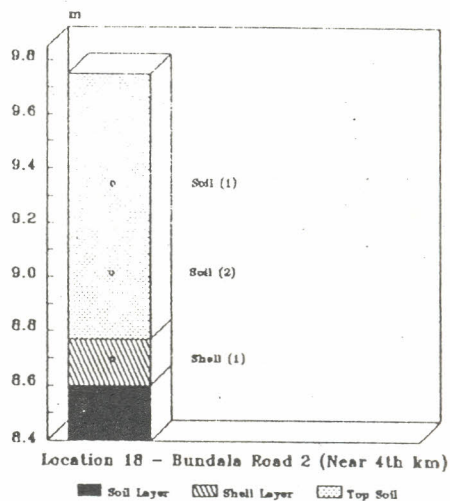
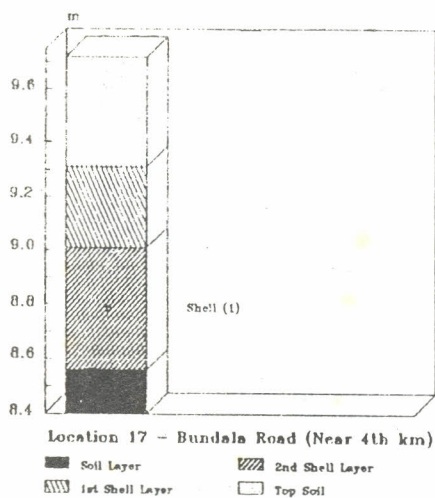


Figure 19: Inorganic contents and grain size analysis of the soil samples 11.1 and 11.2.



Figures 20, 21, 22 and 23: Stratigraphic sequences of the shell beds at location nos. 13, 14, 15 (Karagan 3,4 and 5) and 16 (Bundala 1).



Figures 24, 25, 26 and 27: Stratigraphic sequences of the shell beds at location nos. 17, 18, 19 (Bundala Road 2) and 20 (Koholankala).

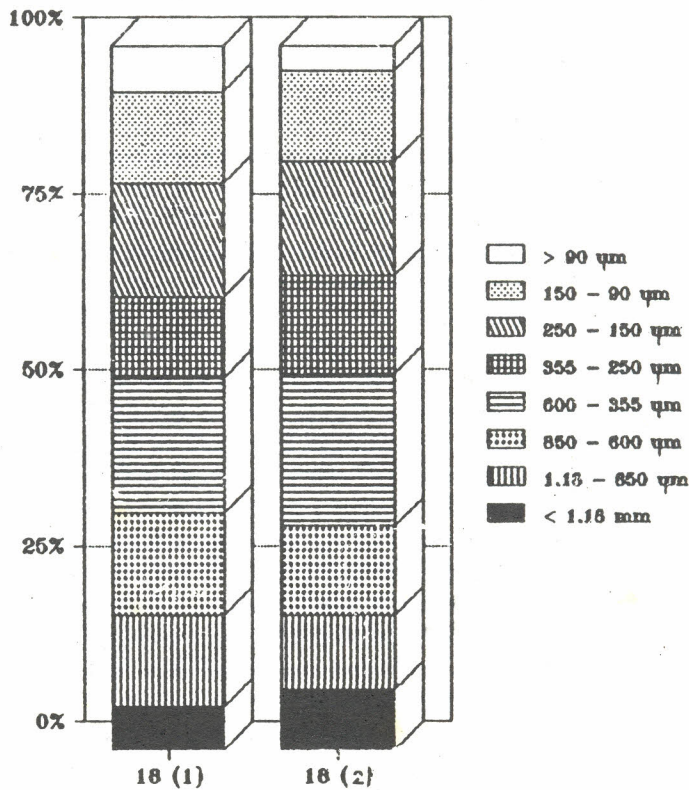
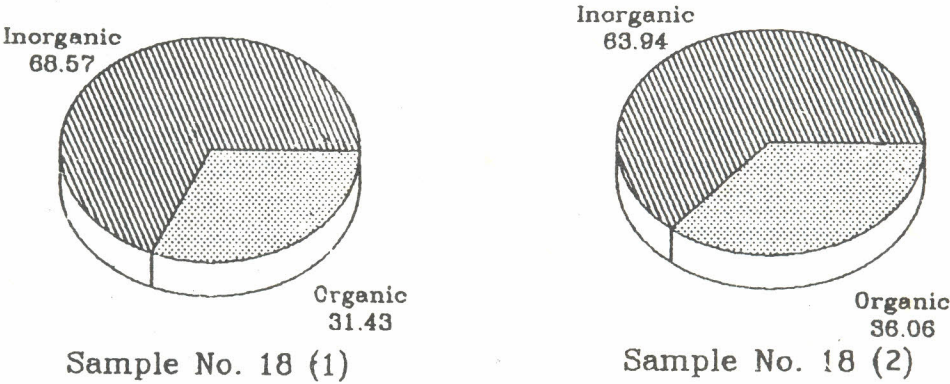


Figure 28: Inorganic contents and grain size analysis of the soil samples 18.1 and 18.2.

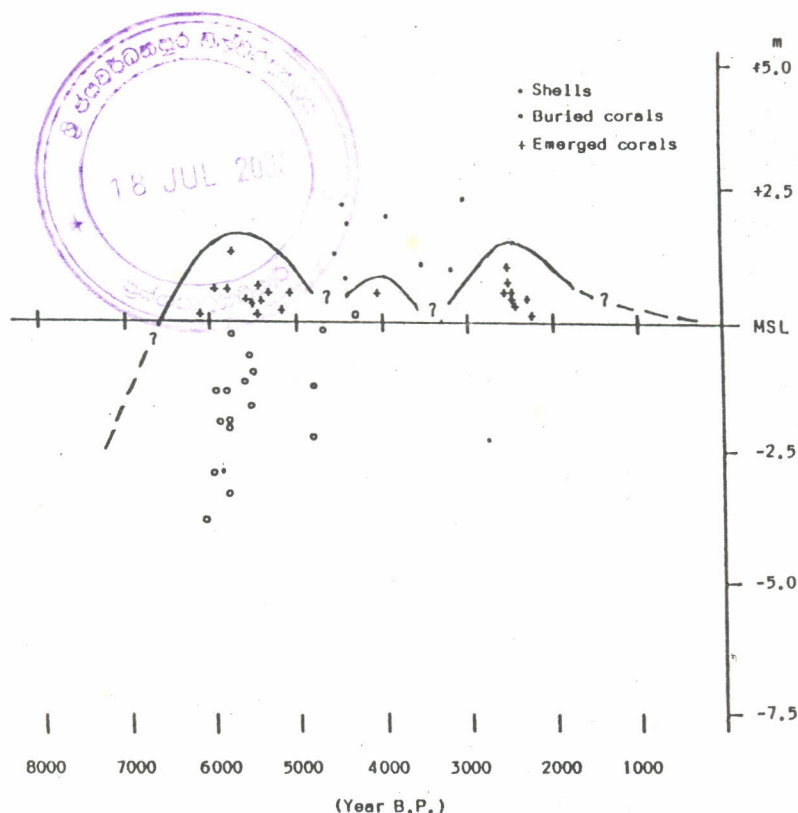


Figure 29: Curve indicates three episodes of high sea-level in Sri Lanka..

The shells of the study area belong mainly to 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). The shell valves in the beds from Kalametiya Kalapuwa to Bundala Kalapuwa belong to a few species; of which the dominant species in *Meretrix meretrix* (Plate 1). The family Arcidae are heavy, squarish, porcelainous clams having a so-called taxodont 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* (Plate 1). The Potamididae included into *Cerithidea cingulata* (Gmelin, 1791) or *Cerithidea ornata* (Plate 1) is a large brackish water group with elongate, solid shells usually dirty brown in colour and many whorled. Most columella live in mangrove and estuarine areas.

The levels of the shell layers, types of the constituents, colour of the soil etc. are described in detail, and shown in Figures 5 to 28 and Plates 1 to 9. The types of shells, live position of the valves, rocky artifacts, animal bones, and human bones which were found from these shell beds are shown in these plates. Many layers of different thickness of constituents and deposition patterns indicate that the shell and shell fragments have been deposited by storm waves especially at Bataata - Gruupokuna (Plate 6). The shell beds at Kalametiya which appeared in many micro-layers can be identified based on the deposition pattern (Plates 7b and 8). The top shell layers contained tiny and small to large shells (below 40 mm in size) of *Meretrix* spp. and *Cerethedea* spp. with calcareous sand which had been piled up by wave action, while the lower layers contained weathered shells and shell fragments. They are mixed with weathered organic material (10 YR 2/1) and calcareous clay. Bluish clay of the bottom layer indicates that the shells have been deposited on a grass biomass.

Emerged Shell Beds and Their Relationship to Sea-level Change

Katupotha¹⁵ recently indicated that the mid-Holocene sea-level was at least 1.5 m above that of the present level with three episodes as follows;

- a) 6240 - 5130 B.P. (first episode of high sea level)
- b) 4390 - 3930 B.P. (second episode of high sea level)
- c) 3280 - 2270 B.P. (third episode of high sea level)

Following these high sea-level episodes, the former drainage basins were submerged forming lagoon 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 being buried between Akurala and Matara thrived on such embayments where factors were suitable for the growth of coral especially on the southwestern and southern coast, while mollusks lived in intermediate and dry zone coastal embayments.

It is suggested that the beachrock, slightly above from the supratidal zone, on the west coast had developed around 3,700 y B.P. during this stage. As evidenced from ¹⁴C dating of shells embedded in emerged reef patches^{16,17} and corals (in a position of growth) from emerged reef patches¹⁷⁻¹⁹ the climatic changes have occurred after the mid-Holocene high sea-level. The lowering of sea level can be recognized between 5030-4390 y B.P. and 3930-3290 y B.P. by ¹⁴C dating of shell beds (Fig. 29 and Table 2).

Table 2: Dated Shell Beds along the Southern Coastal Zone

No	Locality	Elevation (in metres)	Age (yr B.P.) (half-life = 5568 $\pm$ 30)	Laboratory No
1	Hungama	+ 1.3	5780 $\pm$ 20	HR 120
2	Hungama	+ 0.8	4440 $\pm$ 60	HR 264
3	Kalametiya	+ 1.2	3570 $\pm$ 60	HR 265
4	Kalametiya	+ 2.2	4460 $\pm$ 60	HR 266
5	Kalametiya	+ 2.0	3960 $\pm$ 60	HR 267
6	Karagan	+ 2.3	3050 $\pm$ 100	HR 123
7	Udamalala	+ 6.5	4050 $\pm$ 60	HR 122
8	Udamalala	+ 5.0	4650 $\pm$ 70	HR 268

Source: Katupotha 1988b and 1988c.

The bulk of the shells of these beds have been piled up by severe storm wave action on mounds, in lagoon, lake bottoms and on sand dunes and headlands. Present investigations indicate further that the shell valves of lagoon, lake and channel beds (floors of marine and brackish pools) mostly accumulated as *in situ* consequently on the lowering of sea level. Hence, the sea level around 4700 and 3600y B.P. was at its present level or slightly below it. Further, ^{14}C dating of shell beds along the southern coast in the Hambantota district prove such changes have occurred during the late Holocene.^{17,18}

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 subject to local weathering conditions. Thickness of the top soil covered by these means varies locally and sometimes more than 1m thick alluvial soil underline 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.

Conclusion

Stratigraphic sequences of the emerged Holocene shell beds along the southern coast between Kalametiya kalapuwa and Bundala lewaya clearly show that they are marine in origin. The shells of many of these beds have been piled up together with stone artifacts, pieces of pottery, human bones and other animal bones by severe storm wave action on mounds in lagoon and lake bottoms, on sand dunes and headlands. Present investigations of these shell beds further indicate that the shell valves of lagoon, lake and channel beds (floors of marine and brackish

pools) mostly accumulated *in situ* consequently to the lowering of sea level between 5030-4390 and 3930 - 3290y B.P. 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 deposition pattern and different types of artifacts are valuable indicators in the study of geological, archaeological and palaeoenvironmental significance of these beds.

Acknowledgement

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