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Research papers
National Archaeological Symposium
9th & 10th July

II වෙළුම
Volume II

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Old Raised Beaches and Dune Ridges: Evidence from Kiriyankalli to Mundal in Northwest Sri Lanka

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Key words: Raised beaches, Dune ridges, Kiriyankalli, Mundal, Northwest Sri Lanka

Old raised beach and dune ridge formations in the Northwestern coastal zone from Kiryankalli to Mundal are the most distinctive members of the Quaternary System, not only in appearance but also in their topographic expression. It is essentially a clayey sand or loam with characteristic brick-red colour, and forms a number of low, narrow elongated ridges or domes. Due to their brick-red colour these formations are designated as Red Beds. Well developed deposits of Red Beds are noticed from the Baththulu Oya Bridge to Puttalam, and beyond that to Kudremalai.

The origin of these Red Beds and dune ridges extends back to the Quaternary Period. Essentially an outcome of sea level and climatic changes of that time the Red Bed ridges show sequential changes.

The overburden sandy layers in Red Bed dune ridges have been transported by wind action. The red colour of the sand is due to iron oxides mainly ferric and sand reddening due to the time factor. Likewise, it is possible to infer that the colloidal silicaceous material mixed with calcareous material of marine or lagoonal fauna, especially shells, demarcate the limit of paleo marine and terrestrial boundaries between the Quaternary and Neogene Periods.

Introduction

Well developed deposits of old raised beaches and dune ridges are noticed from the Battulu Oya Bridge to (North of Negambo) to Puttalam, and beyond that to Kudremalai. Due to their brick-red colour these formations are designated as Red Beds. The main road from the Maha oya to Chilaw (Peliyagoda-Puttalam A-4 Road) runs along one of these Red Bed ridges, and a conspicuous ridge of the same formation runs along the east side of the road Kiriyankalli to Mundel. Other well known ridges are crossed on the road between palavi and kalladi (the old airport at Puttalam is built on Red Bed). Several elongate ridges of Red Beds are also found between Puttalam and Kudirekmalai, as for an example those near Karativu and Aruakalu hill.

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The thickness of the Red Earth formation varies from place to place, but is usually about 15m to 25m. It may, however, attain thicknesses of over 30m; the maximum recorded being 35m at Aruakalu, and they are consistently aligned in a north-south direction (Wayland, 1919; Coates, 1935, Cooray, 1984).

The formation and distribution of raised Red Bed deposit in Sri Lanka has long interested among geologists, pedologists and sedimentologists. It has been suggested that the nature, degree and progress of reddening in dune sands can be a useful indicator of the relative age and environmental history of the sands (Pye, 1981). Accordingly, these Red Bed deposit is useful indicator to reveal the palaeoenvironment of Sri Lanka.

The Island of Sri Lanka has been subjected to at least four major uplifts during Jurassic, Miocene, Pliocene and Pleistocene time (Pleistocene - *'Glacial Epoch'* and Holocene - *'Recent' for the Post Glacial'* - are two epochs of the Quaternary Period) which broke up its sedimentary beds and altered its topography as a result the earlier sedimentary deposits have disappeared from the greater past of Sri Lanka (Deraniyagala, 1958). The Pleistocene is the first epoch of the Quaternary Period or 6th epoch of the Cenozoic Era (ISC 2009). The end of the Pleistocene corresponds with the retreat of the last continental glacier. Covering the recent period of repeated glaciations of the world, the real Pleistocene is the epoch from 1.8 million to 10,300 years B.P (Before Present). The end of the Pleistocene corresponds with the end of the Paleolithic age used in archaeologists.

During the Last Glacial Maximum, between 23,000 and 19,000 years ago, the total amount of ice accumulated in the glaciers and the continental ice sheets reached its highest point. As the ice accumulated on the continents, it sucked water out of the oceans and caused the sea level to drop. When continental ice accumulation was at its peak, the sea level dropped to between 120 and 140 metres below the current mark (Kolla and Biscave 1977; Prell 1980; Williams 1985; Giresse 1987 and Uriarte 2010). This exposed the continental shelf around Sri Lanka, which can be considered as the submerged peneplain, which was described by Somerville (1907) and Deraniyagala (1958). When deglaciation commenced about 17,000 yrs B.P, sea level began to rise, and the world's climates peaked about 6000 yr B.P, and this designated as Post-Glacial Maxima about a few metres above present MSL in some parts of the world as well as in Sri Lanka (Swan, 1982; Katupotha, 1994, Katupotha & Fujiwara 1989, Katupotha & Wijayananda, 1989, Wijayanada & Katupotha, 1990).

It is possible to suppose most of these chronological sequences have been marked on old raised beach and dune ridges of the northwestern coastal zone of Sri Lanka, which is the most distinctive members of the Quaternary System, not only in appearance but also in its topographic expression.

OBJECTIVES

The main objective of this study is to examine, in detail, the palaeoenvironmental significance of the old raised beaches and dune ridges. Except the Red Beds near Karativu and Aruakalu Hill, the area between Kiriyankalli to Mundal the most significant deposit is the consequence of height from the mean sea level (MSL), colour, main constituents and their physical properties with evolution.

The examination of the evolution and the significance of old beaches and dune ridges will be of immense value to: (a) examine the stratigraphic sequence of the Red Beds; (b) identify main constituents and their physical properties; (c) reveal the palaeo climate and sea level changes; (d) Subsurface faunal and floral remains, and (e) examine the material remains of previous human habitations.

STUDY AREA

A deposit of raised beaches and dune ridge between Kiriyankalli and Mundal is selected to examine in detail, the palaeoenvironmental significance (Figure 1). The A - 4 (Chilaw – Puttalam) Road can be considered as the western boundary of a Red Bed ridge, which slopes towards Mundal Lake and becomes skinny and disappears at the lake edge. The Mundal Lake is sometimes referred to as Mundal lagoon, which is linked to Puttalam Lagoon to the north by a channel. The lagoon water is highly brackish, and surrounded by a region of rice paddies, coconut plantations and scrubland. The marginal land is converted for prawn farming ponds in preference to paddy fields.

The eastern boundary of the Red Bed ridge also slopes about 10 – 8m. A dug well in this boundary area shows that the main deposits consist of fluvial material, and it extends about 8.0m to depth with a coarse clayey sand layer. The rivers (from eastward) including three catchments namely, the Madurankuli Aru, the Kalagamu Oya and the Ratambala Oya supply a considerable amount of terrestrial waters during the rainy season. The tidal creeks stretch along the narrow corridor and both terrestrial and tidal waters deposit layers of fine silt and mud. Hence, the lake and its surrounding are forming up of mud and thin tidal flats.

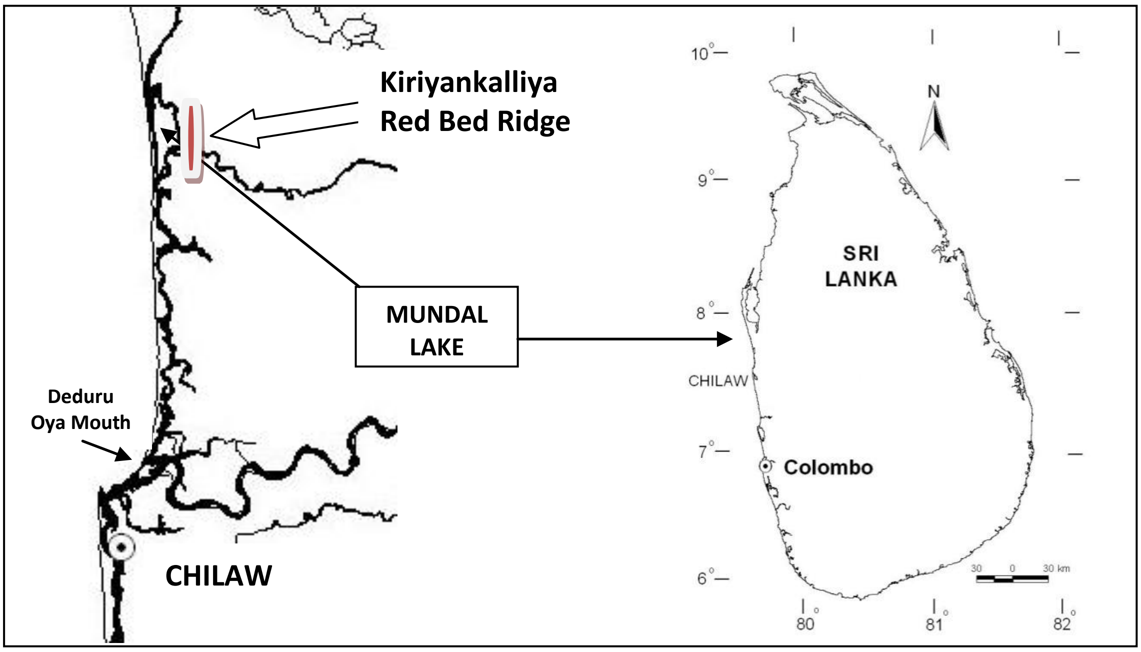


Figure 1. Location of the Red Bed ridge between Kiriyankalliya and Mundalama

The Tide Tables for the past 30-year period indicate that the average tidal amplitude along the west coast is about 80 cm. The lake may finally be converted into a swampy or peaty bog in which dead and decaying vegetation would accumulate to form peat owing this process.

The thickness of the Red Bed ridge of the study area usually varies from place to place with crest about 24.0m high from MSL. Likewise home gardens, residential blocks and coconut estates covered this elongated ridge. The width of the ridge is very from 400m (at Kiryankalliya) to 1.2 km (at Mundalama). A definite terrace is clearly visible near the Maternity Hospital at Kiriyankalli, which is undoubtedly a raised beach. The deposit is wind-blown, largely on the evidence of the small, well rounded quartz grains. The elongated nature of the ridges, their shape in cross-section, and the fact that stretches of marsh and diversions of drainage occur on the east of them, are all points of comprise with the existing barrier beaches.

It is very difficult to find continuous rainfall and temperature data relating to Mundal Lake and Ratambala Oya basin areas. However the limited data available provide sufficient clues to identify sequential drought and flood periods both sides of the Red Bed ridge (Katupotha, 2009). With the lapse of time, increase of population by settlement rather than by the natural growth, improper land use practices such as urban development, deforestation (legal and illegal forest felling in forest reservations and other forests), *chena* cultivation, construction of prawn farms etc. between Mundal Lake and the Red Bed ridge, were instrumental to reduce the surface water storages and ground water levels in the area. Besides, construction of a large number of tube wells has been responsible for the colour and clay content of the Red Bed ridge area.

METHODOLOGY

A filed observation was undertaken as 1st and 2nd Phases to examine the stratigraphic sequence of the Red Bed in the study area and to identify main constituents and the physical properties of the formation.

- GPS measurements were taken at the soil augur observations/dug well observations sites using Spor Trak (Magellan).

- Tube wells were drilled using hand auger (20 cm diameter instrument) to obtain sub surface soil (Photos 1 & 2).

- The colours of the soil were decided using Revised Standard Soil Color Charts (M. Oyama & H. Takehara, 1967).

- Ten cross sections of the Red Bed ridge in the study area were draft using Google Maps and Horizontal and vertical scales were checked using GPS instrument.

- Completed grains size analysis and identification of minerals at the Petrological Laboratory-GSMB.

Photos 1 & 2 Hand drillings at Tube Well No. 1

Location 1 - Drilling point of Tube-Well

A tub-well is located at coordinates 07°54'10" N and 79°49'21"E.

The thickness of the top layer is varied from 0.80 to 1.0m. Brownish black colour, fine root material and clayey conditions of this layer indicate that it is a poorly drained marsh bed. Below this layer, is yellowish fine to coarse sandy deposit. The sands had been piled up by diversions of drainage due to palaeo climate change. Further, beneath this sand deposit, to about 5.0 - 6.0 m depth a well-compact precipitated colloidal silicaceous stratum is seen. This tube-well was drilled down to 23.0m, and shows the same material below.

The colloidal silicaceous material is mixed with calcareous material of marine or lagoonal fauna especially shells. The constituents and the compactness resemble Muthupantiya beds as well as Kalpitiya (Katupotha and Dias, 2002) and Aruakkalu beds.

Location 2 - Dug well Observation

A surveyed dug well is located at coordinates 07°47'50" N and 79°50'16"E.

This particular dug well is used as a drinking water resource. The top layer primarily comprises of loose fine and medium sand, and the horizon is about 15 cm thick followed by a soft sandy clay horizon of about 45.0 cm thick which is yellowish brown in colour. A layer of medium to coarse sand is found below from 60.0 cm to depth extending down to the maximum thickness of 50.0 cm. This particular layer is well compacted and mixed with highly weathered ferruginous gravel patches. These patches are 2.0 to 4.0 cm thick and show red colour due to oxidization. According to constituents of this soil horizon it should be a fluvial deposit in origin. From this layer to about 8.0m to depth coarse clayey sand layer extends below. The colour of this layer varies from pale yellow (5Y 8/3) to light grey (5Y 8/2). This clayey sand profile is completely decomposed rock that extends down to the basement bedrock formation encountered at 9.0m depth. The weathered bedrock is rich in orthoclase feldspar and very coarse quartz sand.

Location 3 - Edge of the Mundalama Lake

Soil auger observation is located at coordinates 07°47'20" N and 79°48'37"E.

This location is situated in the eastern edge of the Mundalama Lake (west to the railway line). From surface level to 30 cm depth light greenish gray colour (10GY 7/1) soil is evident. Medium grain quartz sands and clay are the main constituents of this soil layer. The next layer extends about 1.0m to beneath having coarse grained sand. This layer is light bluish grey in colour (10G 7/1). About 40 – 50 cm of this clayey soil layer contains rounded quartz and ferruginous gravels. From 1.0m to 1.3m (from surface level) the quartz pebbles and ferruginous gravels are abundant. The size of these pebbles and gravel varied between 5.0 mm and 12.0 mm. From this gravel layer to down to 2.0m, the auger sampling was continued. Fine to coarse sandy clay layer of this level is well compacted and was very difficult to auger. Colour varied from greyish to bluish with patches of dark green and dark blue.

Location 4 - Tube well - 2

The Tube Well - 2 is located at coordinates 7°47'30."N and 79°49'51"E, and it was dug up to 12.0m from the surface level. Likewise the site is located in the cross-sections between 3 and 4. The height of the area is about 20m. The stratigraphic sequences and the physical properties are indicated in Table 2.

Location 5 - Tube well - 3

The Tube Well - 3 is located at coordinates 7°47'30"N and 79°49'.50"E. This well was dug up to 11.0m from the surface level and the site is also located in the cross-sections between 3 and 4. The stratigraphic sequences and the physical properties are indicated in Table 2.

Table 1. The stratigraphic sequences and the physical properties of the tube well - 2

Strata No	Constituents	Color Code	Depth m
1	Brownish Gray fine sand	5 YR 4/8	0-0.75
2	Dull Reddish Brown fine sand to Brown fine sand	5 YR 5/3, 5 YR 5/4, 7.5 YR 4/6	0.75-1.65
3	Reddish Brown fine sand	5 YR 4/6	1.65-2.00
4	Dull Orange fine sand	5 YR 6/4	2.40-2.60
5	Dull Orange fine sand, mottled with Light Brownish Gray fine sand	5 YR 6/4, 5 YR 7/2	2.60-3.00
6	Bright Yellowish Brown fine sand, mottled with Light Gray fine sand	10 YR 6/6, 10 YR 7/1	3.00-3.35
7	Dull Reddish Brown fine sand, mottled with Light Gray and Light Brownish Gray fine sand	5 YR 5/4, 5YR 7/1	3.35-4.00
8	Light Brownish Gray fine sand, mottled with Reddish Brown and Bright Brown fine sand	5 YR 7/1, 5 YR 4/8, 7.5 YR 7/6	4.00-5.20
9	Light Brownish Gray fine sand	5 YR 7/2	5.20-5.90
10	Light Gray fine to medium sand	5 YR 8/1	5.90-7.60
11	Light Gray fine sand	5 YR 8/1	
12	Light Gray coarse to fine sand with 3-5 mm pebbles, mottled with Dull Orange coarse to fine sand	5 YR 8/1, 5 YR 7/4	7.60-8.80
13	Coarse sand with clay, 3 mm pebbles are appeared, compact		8.80-9.45
14	Coarse sand with clay, somewhat compact		9.45-10.35

15	Coarse sand with clay, 10 - 12 mm pebbles are appeared, compact		10.35-10.65
16	Coarse sand with clay, ironstone pebbles are appeared, compact		10.65-11.00
17	Coarse sand with clay, 10-15 mm pebbles are appeared, compact		11.00-12.00

Source: Field Observations, 2009.

Table 2. The stratigraphic sequences and the physical properties of the tube well - 3

Strata No	Constituents	Colour Code	Depth m
1	Red fine sand	7.5 R 4/6	0.30
2	Dark Red fine sand	7.5 R 3/4	0.30-2.10
3	Dark Red to Light Red fine sand	7.5 R 3/4, 7.5	2.10-3.90
4	Light Red fine sand	7.5 R 4/8	3.90-4.90
5	Orange fine to medium sand	2.5 YR 6/8	3.90-5.40
6	Yellow Orange fine sand	10 YR 7/8	5.40-6.40
7	Bright yellowish Brown fine to medium sand	10 YR 7/6	6.40-7.00
8	Greyish Yellow fine to medium sand	2.5 YR7/2	7.00-7.60
9	Light Grey medium sand	2.5 Y 8/1	7.60-9.45
10	Light Grey fine to medium sand		
11	Dull yellow Orange medium sand with clay, compact (3-5 mm pebbles are found)	10 YR 7/2	9.45-10.45
12	Yellow Orange medium to coarse sand with clay, compact (3-5 mm pebbles)	10 YR 7/1	10.45-11.00

Source: Field Observations, 2009

Photos 3. Sequence of Light Red fine sand to Grey fine to medium sand and Photo 4. Light Grey fine to medium sand from Tube well 2.

Grain size and Mineralogical Analysis

Grain size analysis and mineralogical analysis conducted of samples collected at depth of 0.61m, 2.13m, 6.40m and 8.23m respectively in Tube Well (TW) - 2. The results of sieve analysis are shown in Annex 2 and constituents' percentages in each sample are shown in Table 3.

Table 3. Identified constituents from surface to beneath of TW - 3

Types based on grain size	TW - 3 Depth 0.61m	TW - 3 Depth 2.13m	TW - 3 Depth 6.40m	TW - 3 Depth 8.23m
Gravel	1.12%	2.26%	1.89%	0.69%
Coarse sand	12.29%	17.22%	19.78%	24.23%
Fine to medium	85.92%	79.77%	74.07%	74.63%
Silt	0.67%	0.75%	4.26%	0.45%
	100.00	100.00	100.00	100.00

Source: Field Observations, 2009

Table 3 clearly shows that the gravel content is around 2.0m to depth gradually decreasing. Also, coarse sand and fine to medium sand show similar characteristics. But, at about 6.4m depth from the surface, the silt content is exceeding 4% and by 8.0m it is decreasing. Thus the content of fine to medium and, coarse sand and gravel in level show the physical behaviour during their deposition. Likewise, increasing of silt content around 6.4m may be a result of percolation of water on the sand ridge.

Mineralogical analysis also conducted in the same Tube Well 3 at the depth of 0.61m and 2.13m. Heavy minerals and floats were separated using Bromoform (CHBr3). For the mineralogical analysis of Sample 1 (0.61m), 55.64g was taken as initial weight. After Bromoform separation, the heavies (heavy minerals) were 7.05g. This amount used for Electromagnetic separation using different Amp/slopes. After separation, the heavies were 6.6926g and lost as waste 0.3574g (Table 4).

Table 4. Electromagnetic separation of heavies at of 0.61m depth in TW - 3

Amp/Slope	1/0	0.3/15	0.4/15	0.5/15	0.8/15	1.2/15	1.2/5	N. mag	Total
Ilmenite	0.19	3.32	0.6825	0.175	0.009				4.3765
Leucoxine			0.0288	0.0295	0.0099	0.0076			0.0757
Garnet			4E-05	0.006					0.0060
Hornblende				0.0037					0.0037
Spinel				0.0244	0.0225	0.1758	0.3135		0.5361
Monazite					0.0468	0.0025	0.0083		0.0575
Rutile					0.0018	0.0038	0.154	0.48354	0.6431
Sillimanite								0.82425	0.8242
Zircon								0.1696	0.1696
Total	1.19	3.32	0.7113	0.2385	0.09	0.1897	0.4758	1.47739	6.6924

N. mag = Non Magnetic

The floats consisted of sub-angular to angular clear milky quartz sand. Large grains are sub-rounded. Small grains are sub-angular to angular, No feldspar and calcareous material are appeared.

Table 5. Heavy mineral concentration in the sample at 0.61m depth (TW – 3)

Type	Total W.			Percentage
Floates	48.590	55.283	100	87.894
Ilmenite	4.376	55.283	100	7.917
Sillimanite	0.824	55.283	100	1.491
Rutile	0.643	55.283	100	1.163
Leucoxene	0.076	55.283	100	0.137
Monazite	0.058	55.283	100	0.104
Spinel	0.536	55.283	100	0.970
Zircon	0.170	55.283	100	0.307
Garnet/ Hornblende	0.010	55.283	100	0.017
	55.283			100.000

The ilmenite of the sample is black and brown in clours and majority of grains are sub-rounded. Garnets are sharply angular. Sillimanite is angular to sub-angular. Although, spinels have 7.5-8.0 hardness, they are well rounded to sub-angular, large grains are well rounded. Leucixine are rounded. Hornblendes are angular. As well Rutile and Zircon are sub-angular and sub-rounded. The physical behavior and physical properties of the above minerals manage due to the specific gravity and hardness. These minerals of the sand ridge show that they are windblown in origin and they are worn-out during the transportation process.

Mineralogical analysis of sample 2 (at 0.61m depth of Tube Well 3), the floats were mostly sub-rounded grains of quartz with pale yellow to deep yellow colour. Quartz represents 98% and other 2% (mainly rock fragments - feldspar. Electromagnetic separation shows that magnetite is the most significant mineral in this sample.

Mineralogical analysis of Tube Well at depth 10.97m conducted using same procedure. The floats are 100% quartz, and show the sub-rounded to rounded shapes. Mineral Ilmenite at this level shows that sub-rounded to sub-angular shape. Spinel, monazite, lencoxene and tourmaline are mostly rounded. Also, nonmagnetic minerals such as silimanite and rutile are sub-angular. Beside the above gold appears as trace, but no economic value at this depth and quantity. All these minerals also may be windblown in origin.

DISCUSSION

All the cross sections show that the maximum height is varied between 21 and 23m, and minimum thicknes of the Red Bed deposit is varied around 8 – 9m. The Railway Line and the Chilaw – Puttalam A - 4 Road are running parallel to the Red Sand ridge, and the main road can consider as a western boundary of the Red Bed ridge. The height of this boundary, along the study area has about 8 – 10m and is sloping towards the Mundalama Lake. The Red Bed deposit layer in this slope area is become skinny at the lake coast. Likewise, at the eastern side of the Red Bed ridge is also sloping about 10 – 8m. At this level the main deposits consisted by fluvial material, and marshy bed has developed as an overburden in a later stage.

The ten cross sections, which are annexed here (Annex 1) have arrayed from north to south from Praja Jala Padana (Cross section 1, A-B) to Kiriyankalliya near Pullichchikulama (Cross section 10, S-T). The latitude and longitude coordinates are indicated at the beginning (west) and end (east) points. The horizontal scales represent here is useful to understand the maximum and minimum width of the study area. Accordingly, the maximum width is about 1200m (Cross section 1, A-B) and minimum width is about 300m (between Cross section 4, G-H and Cross section 7, M-N). The minimum width of this ridge should be a result of fluvial erosion towards the Battulu Oya.

The stratigraphic sequences, colour of the constituents have been discussed based on soul auger observation and tube wells. Both Location 1 - Drilling point of tube well and Location 2 - Dug well observation point are close to the study area, and located in marshy lands with diversions of drainage on the east are laid on the Precambrian basement. The bottom layer in many places of the marshy beds in and around of the sites is covered by well sorted quartz sand and the bottom layers comprise fluvial deposits. The coarse clayey sand layers in both sites piled up by diversions of drainage due to palaeo floods. Although, beneath this sand deposit to about 5.0 - 6.0 m depth a well-compact precipitated colloidal silicaceous stratum is seen in Location 1, but there is no such a layer at Location 2. This tube-well (Location 1) was drilled down to 23.0m, and shows the same material below, however in Location 2 clayey sand profile is completely decomposed rock that extends down to the basement bedrock formation encountered at 9.0m depth. Based on the sub surface layers in the area it is possible to infer that the colloidal silicaceous material mixed with calcareous material of marine or lagoonal fauna especially shells demarcate the limit of paleo marine and terrestrial boundaries.

About 2.00m depth from the surface in Tube Well - 2, the fine sandy layers has Dull Reddish Brown fine sand to Reddish Brown fine sand. The reddish brown colour of the sand is due to iron oxides mainly ferric. From 2.00m to 5.20m to beneath this Tube Well, the colour of the fine sand differ Dull Orange, Bright Yellowish Brown to Light Gray due to coated with iron hydroxide the quartz sands. Lack of oxidisation to depth from 5.20m to 8.80m, the fine sand have grey colour, and from this level to depth the constituents are differed from fine to coarse sands with quartz pebbles. The coarse sand with 3 mm sized pebbles from 8.80m to depth have became well compact due to clay content, and the compactness has made by the overburden fine sand layers. From 8.80m to beneath, the compact coarse sandy layers have well rounded quartz pebbles and sometime ferruginous gravels varying with 3.0 – 15.0 mm in size. These stratigraphic sequences of this tube well clearly indicate that the coarse sand with gravels have been transported by paleo floods and fine sands of the overburden layers have been transported by wind action. The red colour of the sand gained due to iron oxides mainly ferric and sand reddening due to the time factor.

The location No 4 – Tube Well 3 has drilled to 11.00m depth from surface and the area is about 20.00m high from MSL. It is also located between 3 and 4 Cross Sections and crest of the ridge. Dark Red fine sand layers in the tube well area extends about 3.90m and from that level to beneath Light Red to Yellow Orange fine sands extend up to 6.40m to depth. The red colours of the sands have expanded due to iron oxides and light coloured are the results of coating with iron hydroxides. The particle sizes of the sands are varied from fine to medium at these coloured layered especially at 5.40 - 7.60m depth. From this level to end level (11m depth) it is possible to obtained well sorted fine to medium (light grey) sands. From 9.45m to depth the sand layers are well compacted due to overburden red bed deposit and compact layers constituent by medium to coarse sand, clay and well rounded 3-5 mm quartz pebbles. The stratigraphic sequences of the Tube Well 3 also emphasized that the particles of the compact layer have been transported by flood waters and overburden red sands deposited by wind action.

One of the major contributory factors for area is the extraction of water without any limitation from dug and tube wells for domestic uses as well as for agriculture. Along the ridge, even in crest area good quality of water is found at depth between 8.0 and 9.0m.

This clearly indicate that the water quality of the tube wells close to the lagoon and along the western side of the Red Bed ridge is salty or brackish taste and the eastern side is bitter taste. Similarly, in some wells which are deeper than 12.0m or under the compact layer water has salty and bitter taste. This is a result of a location of ‘water wedge’ from lagoon area to the marshy lands with diversions of drainage area on the east. Accordingly, the water wedge of the area is located 1.0 - 2.0m at lagoon level, below the 12.0m at the crest area of Red Bed ridge and 2.0 – 3.0m at the marshy area. Due to extraction of water without any limitation from tube wells the water wedge is bent towards the crest.

CONCLUSION

Old raised beach and dune ridge formations of the North West are one of the most distinctive members of the Quaternary System, not only in appearance but also in its topographic expression. It is essential a clayey sand or loam with characteristic brick-red colour, and forms a number of low, narrow elongate ridges or domes. Due to brick-red colour this formation designated as Red Beds, and home gardens, residential blocks and coconut estates covered this elongated ridge.

A definite terrace is clearly visible near the Maternity Hospital at Kiriyankalli, which is undoubtedly a raised beach. The deposit is wind-blown, largely on the evidence of the small, well rounded quartz grains. The elongated nature of the ridges, their shape in cross-section, and the fact that stretches of marsh and diversions of drainage occur on the east of them, where sloping from the crest area to 8-9m.

The stratigraphic sequences of tube wells clearly indicate that the coarse sand with gravels have been transported by paleo floods and fine sands of the overburden layers have been transported by wind action. The red colour of the sand gained due to iron oxides mainly ferric and sand reddening due to the time factor.

One of the major contributory factors for area is the extraction of water without any limitation from dug and tube wells for domestic uses as well as for agriculture. Along the ridge, even in crest area good quality of water is found at depth between 8.0 and 9.0m. This clearly indicate that the water quality of the tube wells close to the lagoon and along the western side of the Red Bed ridge is salty or brackish taste and the eastern side is bitter taste. Similarly, in some wells which are deeper than 12.0m or under the compact layer water has salty and bitter taste. This is a result of a location of 'water wedge' from lagoon area through Red Bed ridge towards the flood plain (marshy lands with diversions of drainage area) on the east. However, it was not possible to reveal subsurface faunal and floral remains as well as to examine the material remains of previous human habitations due to lack of suitable samples.

ACKNOWLEDGEMENT

This study has been sponsored by the Ministry of Environment (Former Ministry of Environment and Natural Resources). We are grateful to Mr. Gamini Gamage, Director, Biodiversity Secretariat, Ministry of Environment. Our special thanks to Professor Gamini Adikari, Chairman of the Palaeobiodiversity Advisory Group, who helped in many ways throughout the study.

A special note of thanks extended for Mr. M.B.U.H. Silva (Petrological Laboratory-GSMB) for identifying and analysing soil samples. Thanks are extended to Dr. N. P. Wijayananda, Chairman of GSMB who gave us his kind permission in the completion of this report.

Thanks are also extended to Mr. W. Asoka Niranjan Fernando, Akash Construction, Puttalam Road, Mundala for helping to collect soil samples and water samples from tube wells, and Research Assistants Mr. Priyantha Ariyathilaka; Mr. Dinesh; Ms. Hasula Wickremasinghe, Biodiversity Secretariat; Ms. H. Sewvandi, Foundation Waterwell Enginnering (Pvt) Ltd and Mr. Pathmakumara Jayasingha, CCF for their help on this report.

References

Coates, J.S., 1935. The Geology of Ceylon. Spolia Ceylanica. 19 (2): 101.187.

Cooray P.G., 1984. An Introduction i the Geology of Sri Lanka. Revised Edition, Ceylon National Museum Publication, Colombo.

Cooray P.G and Katupotha, J. 1992. Geological evolution of the coastal zone of Sri Lanka. Proc., Symposium on "Causes of Coastal Erosion in Sri Lanka". CCD/GTZ, Colombo, Sri Lanka, 9-11, Feb. 1991, 5-26.

Deraniyagala, P.E.P., 1958. The Pleistocene of Ceylon. Ceylon National Museum Publication, Colombo.

ISC, 2009. International Stratigraphic Chart, ICS (International Commission on Stratigraphy), IUGSශ

Katupotha, J., 1994. Quaternary Research in Sri Lanka. Jnl. Geol. Soc. of Sri Lanka. 5, 141-152.

Katupotha, J., 2009. Water Shortage in the Lower Deduru Oya Basin National Conference on Water, Food Security and Climate Change in Sri Lanka, Volume 1- Irrigation for Food Security, 1-21.

Katupotha, J & Dias, Priyalal., 2009. Katupotha J and Dias, Priyalal (2002). Palaeo Stratigraphy of the Muthupamtiya Lagoon, Western Coastal Zone of Sri Lanka (in preparation for publication).

Katupotha, J. and Fujiwara, K., 1988. Holocene sea level change on the southwest and south coasts of Sri Lanka. Palaeogeography, Palaeoclimatology, Palaeoecology, 68, 198—203.

Katupotha, J. and Wijayananda, N.P., 1989. Chro nology of inland shell deposits on the southern coast of Sri Lanka. Quaternary Research, 32, 222—228.

Kolla, N. and Biscave, P.V., 1977. Distribution and origin of quartz in the sediments of the Indian Ocean. Journal of Sedimentary Petrology, 47(2), pp.642-649.

Pye, K. 1981. Rate of dune reddening in a humid climate. Nature 290, 582-584.

Sommerville, B. T. 1907: The submerged plateau surrounding Ceylon, *Spol. Zeylanica*, 5 (18), 69-79.

Swan, B., 1982. The Coastal Geomorphology of Sri Lanka: An introductory Survey. University of New England, Armidale, New South Wales, Australia.

Uriarte, Antón. 2010. Chapter 9. The Last Glacial Maximum, Earth's Climate History, 22 November 2010, http://web.me.com/uriarte/Earths_Climate/Earths_Climate History.

Wayland, E J., 1919. An outline of the stone age of Ceylon. Spolia Zeylanica., 11: 85-125.

Wijayananda, N.P. and Katupotha, J. 1990. Geology and chronology of the inland coral deposits around Akurala. Journal of the Geological Society of Sri Lanka 2, 44-48. Journal of the Geological Society of Sri Lanka. 2, 44-48.

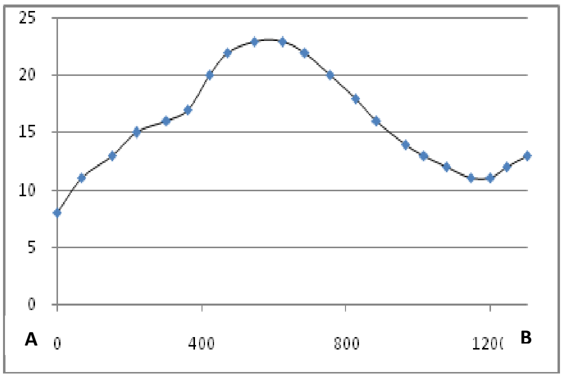
Williams, M.A.J., 1985. Pleistocene aridity in Tropical Africa, Australia and Asia. In: Spencer, D. and Spencer, T. (eds.), Environmental Change and Tropical Geomorphology, pp. 219-233.

Appendix 1

Cross Section 1
Location from A to B

Lat. 7.48.11 Lon. 79.49.27

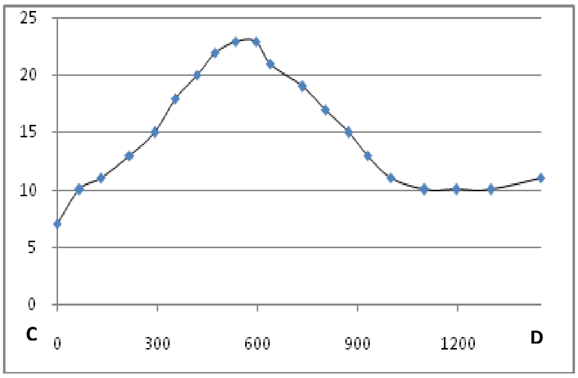
Lat. 7.48.11 Lon. 79.50.10



Cross Section 2
Location from C to D

Lat. 7.47.59 N Lon. 79.47.27E

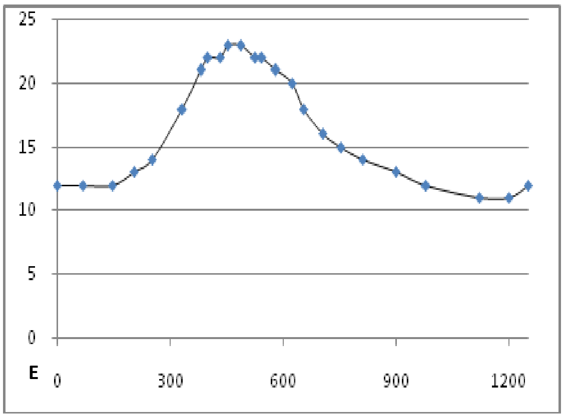
Lat. 7.47.59 N Lon. 79.50.14 E



Cross Section 3
Location from E to F

Lat. 7.47.47 N Lon. 79.49.30 E

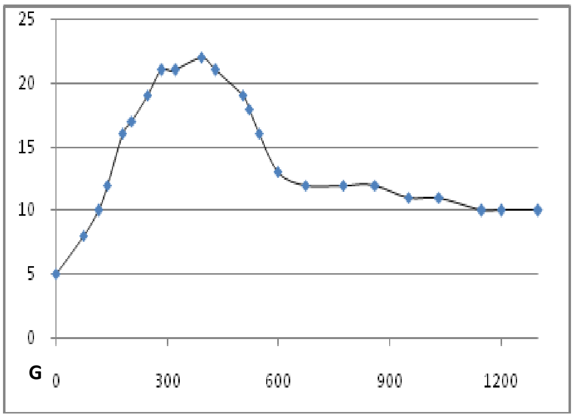
Lat. 7.47.47 N Lon. 79.50.11 E



Cross Section 4
Location from G to H

Lat. 7.47.18 N Lon. 79.49.35

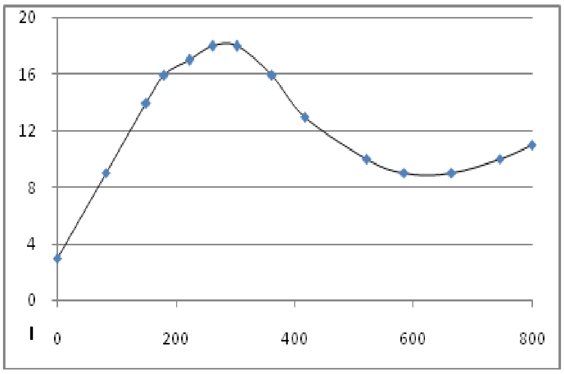
Lat. 7.47.19 N



Cross Section 5
Location from I to J

Lat. 7.46.42 Lon. 79.46.42

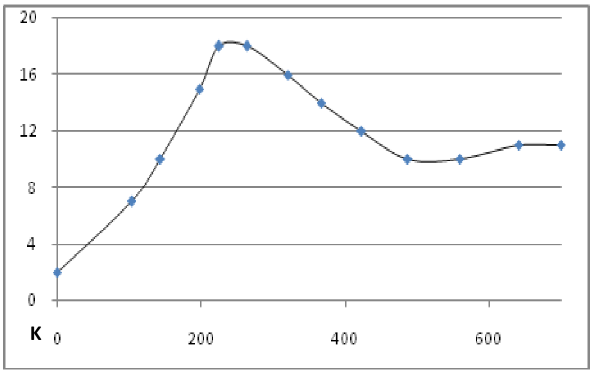
Lat. 7.46.42 Lon. 79.50.06



Cross Section 6
Location from K to L

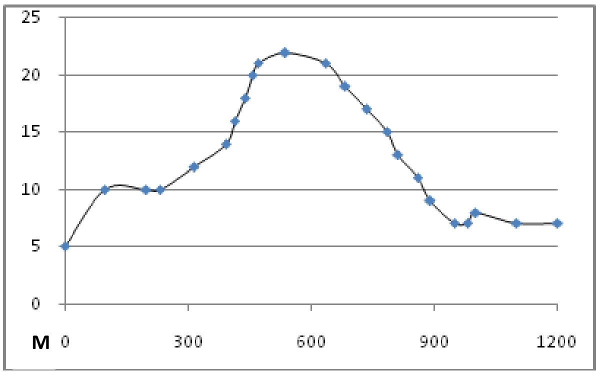
Lat. 79. 46.24 Lon. 7. 49.20

Lat. 7.46.24 Lon. 79.50.03



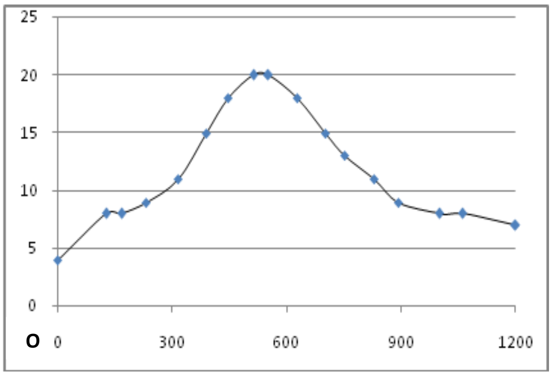
Cross Section 7
Location from M to N

Lat. 7.45.41 Lon. 79.49.35 — Lat. 7.45.37 Lon. 79.50.14



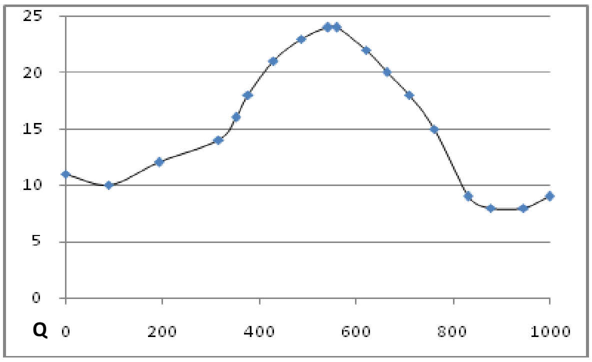
Cross Section 8
Location from O to P

Lat. 7.45.32 Lon. 9.49.36 — Lat. 7.45.32 Lon. 79.50.15



Cross Section 9
Location from Q to R

Lat. 7.45.17 Lon. 79.49.38 — **Lat. 7.45.17 Lon. 79.50.10**



Cross Section 10
Location from S to T

Lat. 7.45.00 Lon. 79.49.34 — **Lat. 7.45.00 Lon. 79.5016**