SEA LEVEL CHAMGES – GLOBAL AND SRI LANKA: AN OVERVIEW

Professor J. Katupotha (Emeritus Professor)
Department of Geography
University of Sri Jayewardenepura
Nugegoda, Sri Lanka

Expert Dialogue Forum on Blue Green Economy & Sustainable Natural Resources
17th - 19th October 2016
Minilaka Medura, BMICH, Colombo

SEA LEVEL CHAMGES – GLOBAL AND SRI LANKA: AN OVERVIEW

The presentation emphasizes the following topics

- **Sea level changes**
- **Sea level indicators**
- **Global sea level changes**
- **Sea level changes in Sri Lanka**

In 1980s, to study the global sea levels, the two books were very important.

Sea-level research: a manual for the collection and evaluation of data

EDITED BY

Orson van de Plassche

Free University, Amsterdam
a contribution to Projects 61 and 200

Sea-level changes.

EDITED BY
MICHAEL J. TOOLEY and IAN SHENNAN

Publisher Basil Blackwell (IBG Special Publication Series 20) 1987

By 2016, large numbers of books, articles were published and Conferences, Seminars, Forums, Groups etc. were held in National and International levels in relation to the palaeo sea level changes.

Glaciation

For a number of reasons, the volume of glacial ice near the poles waxes and wanes over time.

As a result, water is alternately taken from or added to the world oceans. This can result in sea-level oscillations of up to 200 meters.

For example, modern continental glaciers are 1.5 to 2.5 km^3 thick and have a total estimated volume of 33 million km^3.

If we assume the maximum volume of Pleistocene glaciers to have been 71.3 million km^3, then the difference is 38 million km^3.

Using the assumption that glacial water volume is 91.7% of the volume of sea water from which it is derived, a sea-level drop of 106 m can be accounted for by Pleistocene glaciations.

Melting of the present Greenland and Antarctic glaciers would produce a sea-level rise of approximately 60 meters.

Since 18,000 years ago, sea level has been rising in response to the melting of glacial ice, mainly from the Laurentian and the Scandinavian ice sheets of northern Canada.

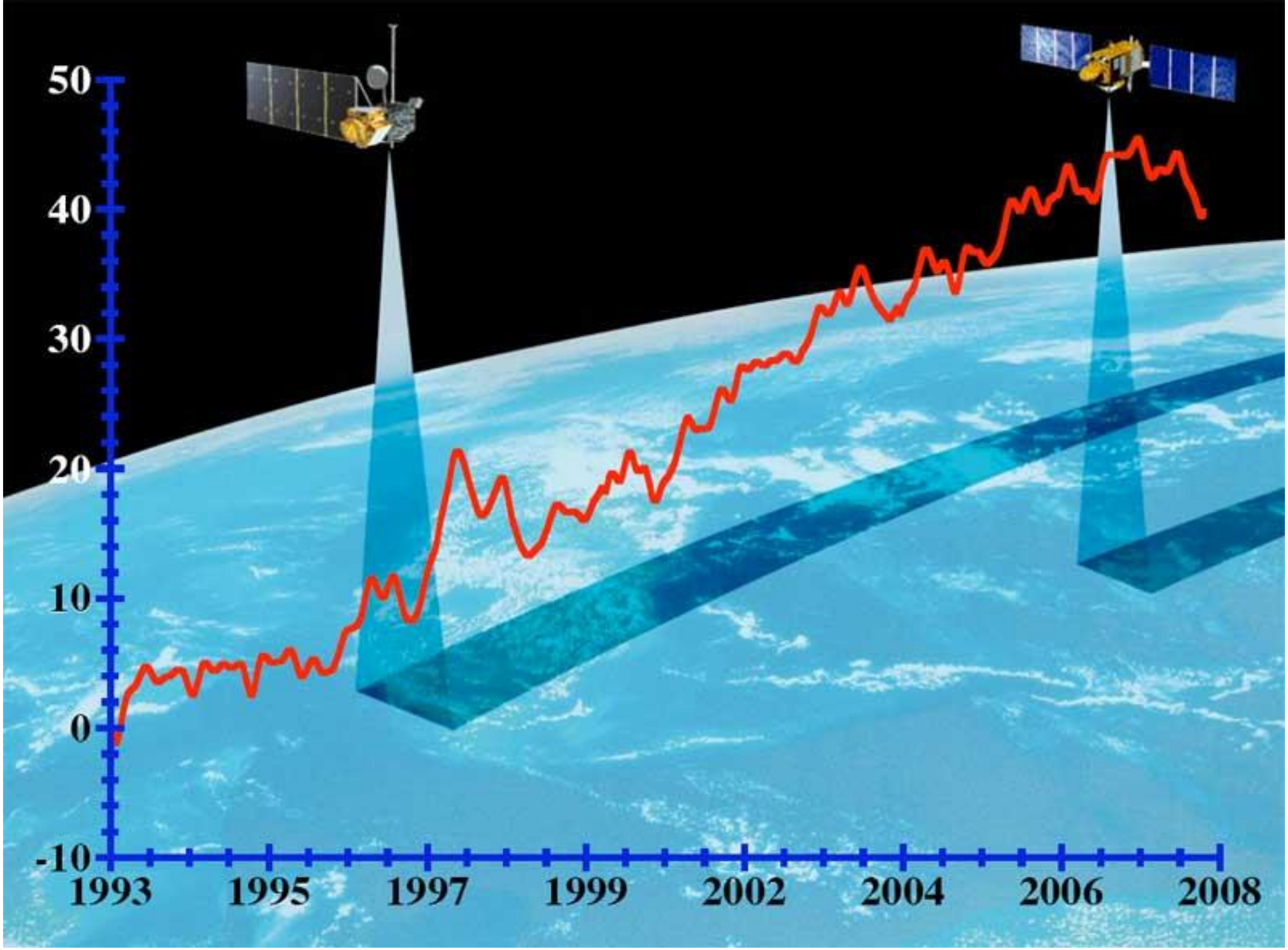
Rapid changes in the oxygen isotopic composition of skeletal foraminifera and corals (melt water has a low O^{18}/O^{16} ratio) indicate that this rise was not uniform; two major and several minor pulses of melt water were added to the ocean.

Based on gaps in the branching-coral (*Acropora palmata*) record offshore of Barbados, Fairbanks (1989) proposed major melt water rhythms at about 14,000 and 11,000 yr BP.

Whatever the actual age or number of melt water rhythms, the main point is that sudden changes in glacial volume have resulted in significant and rapid transients in sea level.

In addition to sea-level changes caused by the transfer of seawater to and from glaciers, sea water volume can change due to thermal expansion and contraction -- for every 1^{o} C decrease in the mean temperature, world-wide sea level will drop by 2 m.

Fauna from Pleistocene ocean sediments suggest a 5 degree lower surface temperature at that time, which would have resulted in a 10-meter lower sea level due only to thermal contraction (reduction).



This graph shows the rise in global sea level (in millimeters) measured by the NASA/CNES ocean altimeter mission TOPEX/Poseidon (on the left) and its follow-on mission Jason-1. Image credit: University of Colorado

Review

Sea level: A review of present-day and recent-past changes and variability

Benoit Meyssignac*, Anny Cazenave

LEGOS-CNES, Toulouse, France

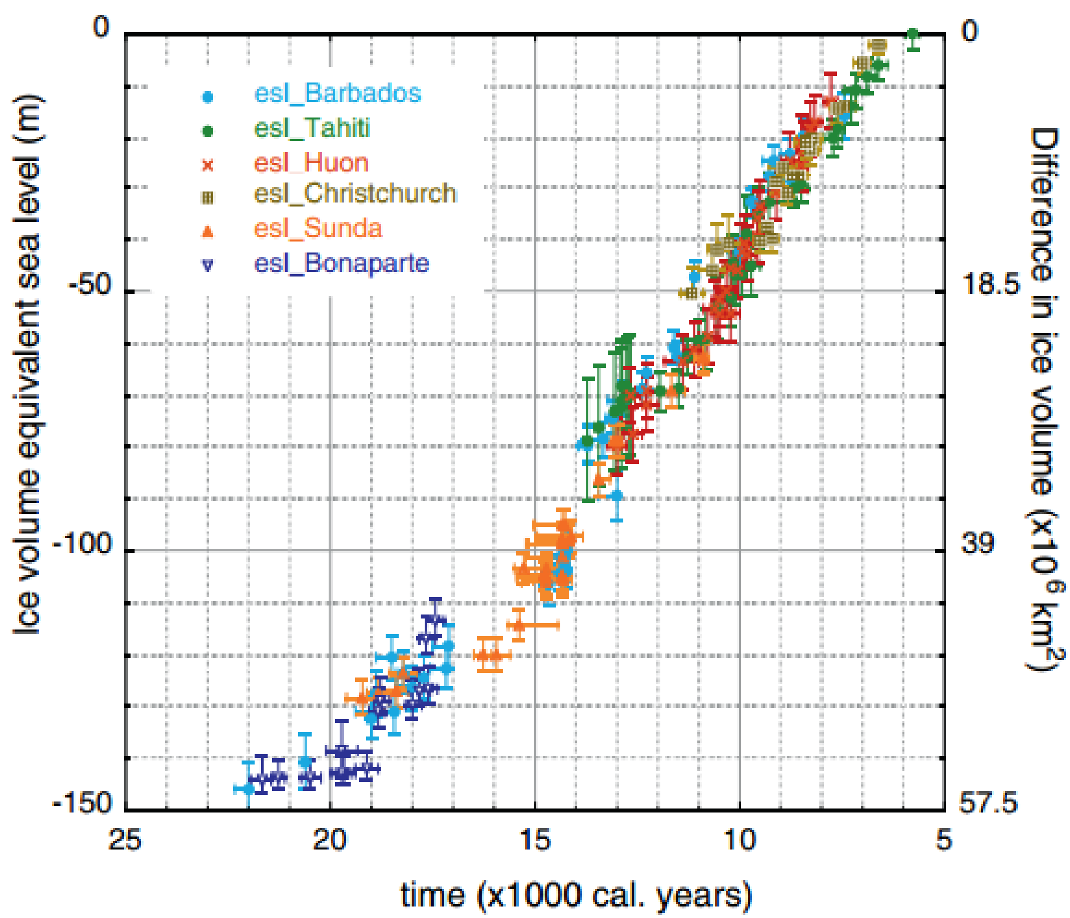
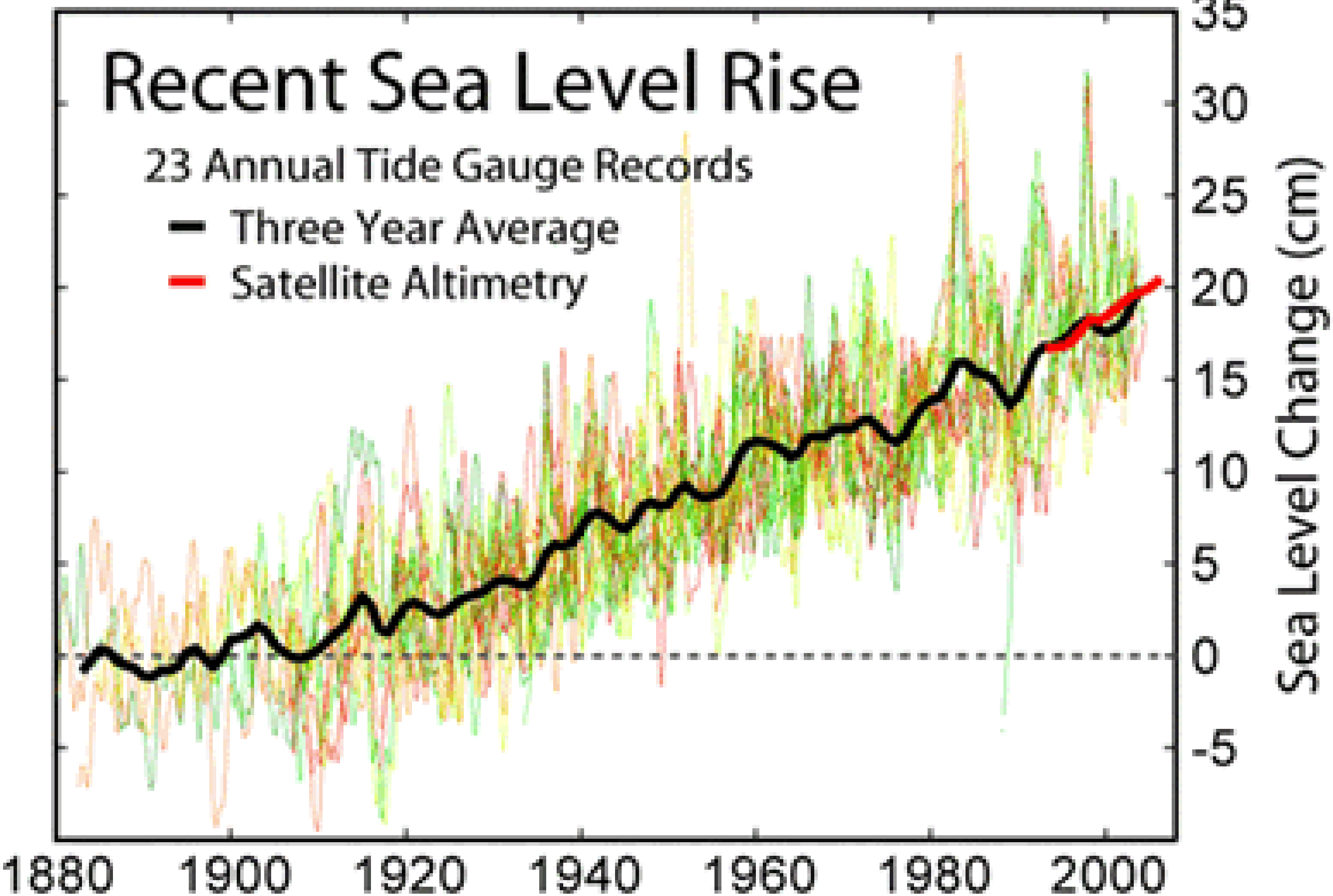
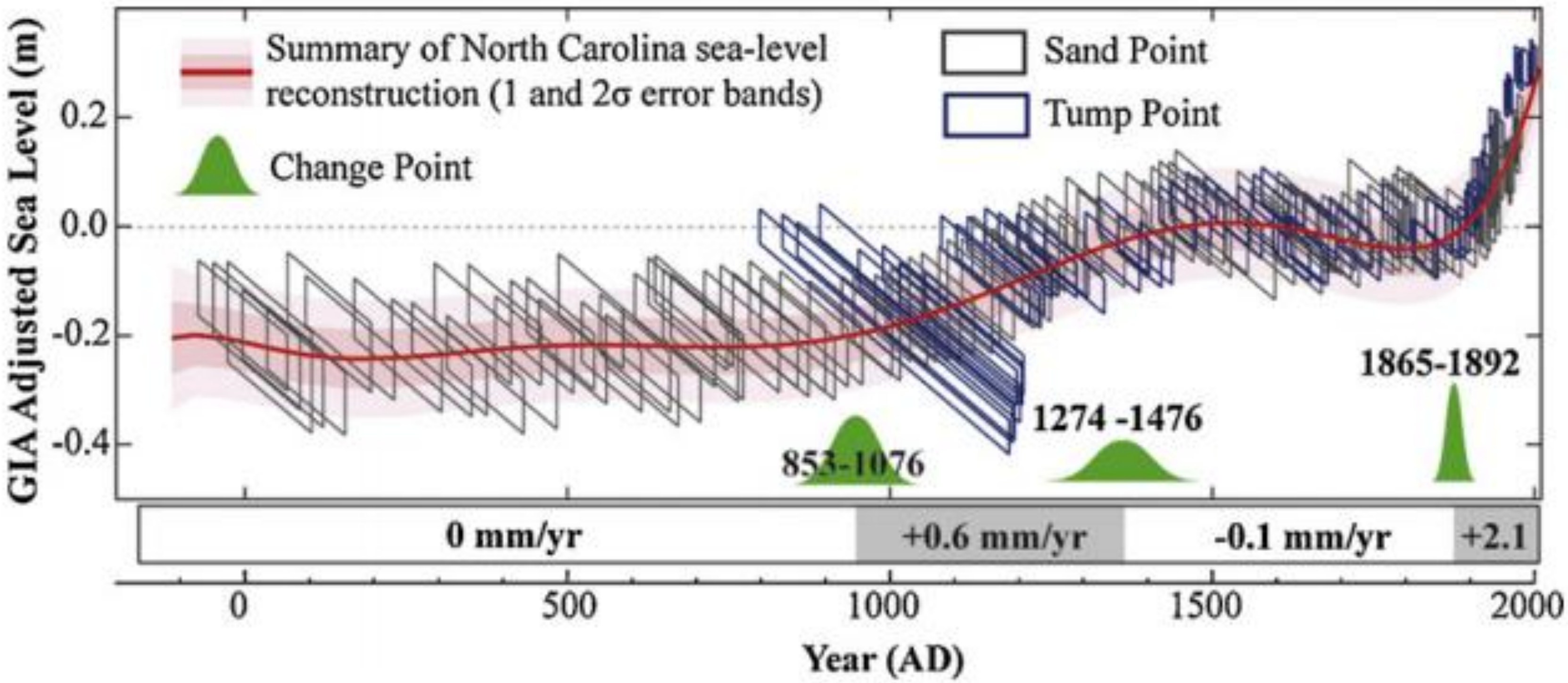


Fig. 1. Changes in global ice volume and sea level equivalent from the last glacial maximum to the present. The figure shows ice-volume equivalent sea level for the past 20 kyr based on isostatically adjusted sea-level data from different localities (updated from Lambeck et al., 2002 with a revised dataset for the Sunda shelf from Hanebuth et al., 2009).



Recent Sea Level Rise
23 Annual Tide Gauge Records
Three Year Average
Satellite Altimetry
Sea Level Change (cm)
35
30
25
20
15
10
5
0
-5
1880
1900
1920
1940
1960
1980
2000



Relative sea level reconstruction for the last 2000 years from salt-marsh data analyses. (From Kemp et al., 2011.)

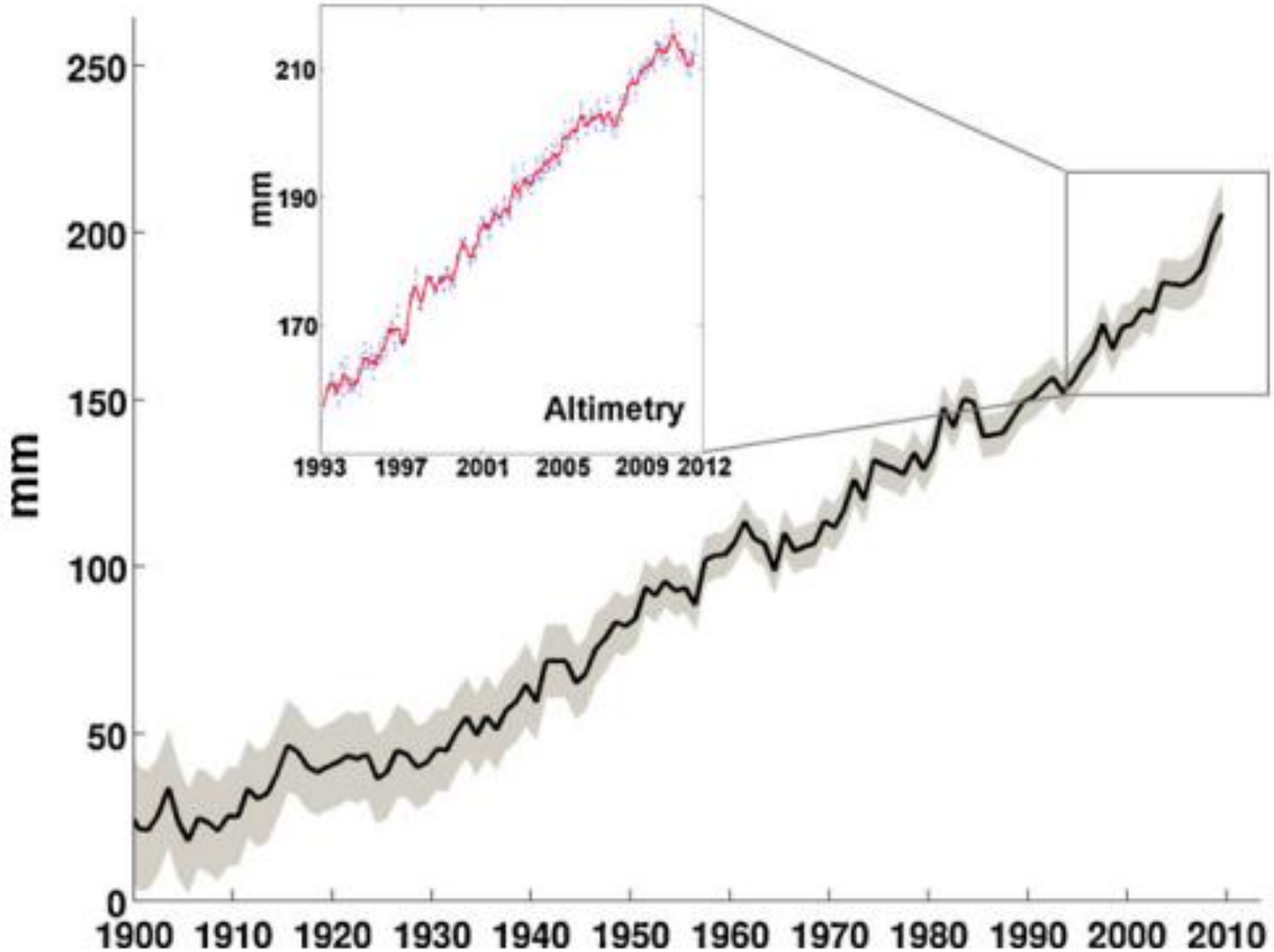


Fig. 3. 20th century sea level curve (in black and associated uncertainty in light gray) based on past sea level reconstruction using tide gauge data and additional information (from Church and White, 2011). In the box: altimetry-based sea level curve between 1993 and 2011 (data from AVISO; http://www.aviso.oceanobs.com/en/data/products/sea-surface-height-products/global/msla/index.html) (blue points: data at 10-day interval; the red curve is based on a 3-month smoothing of the blue data).

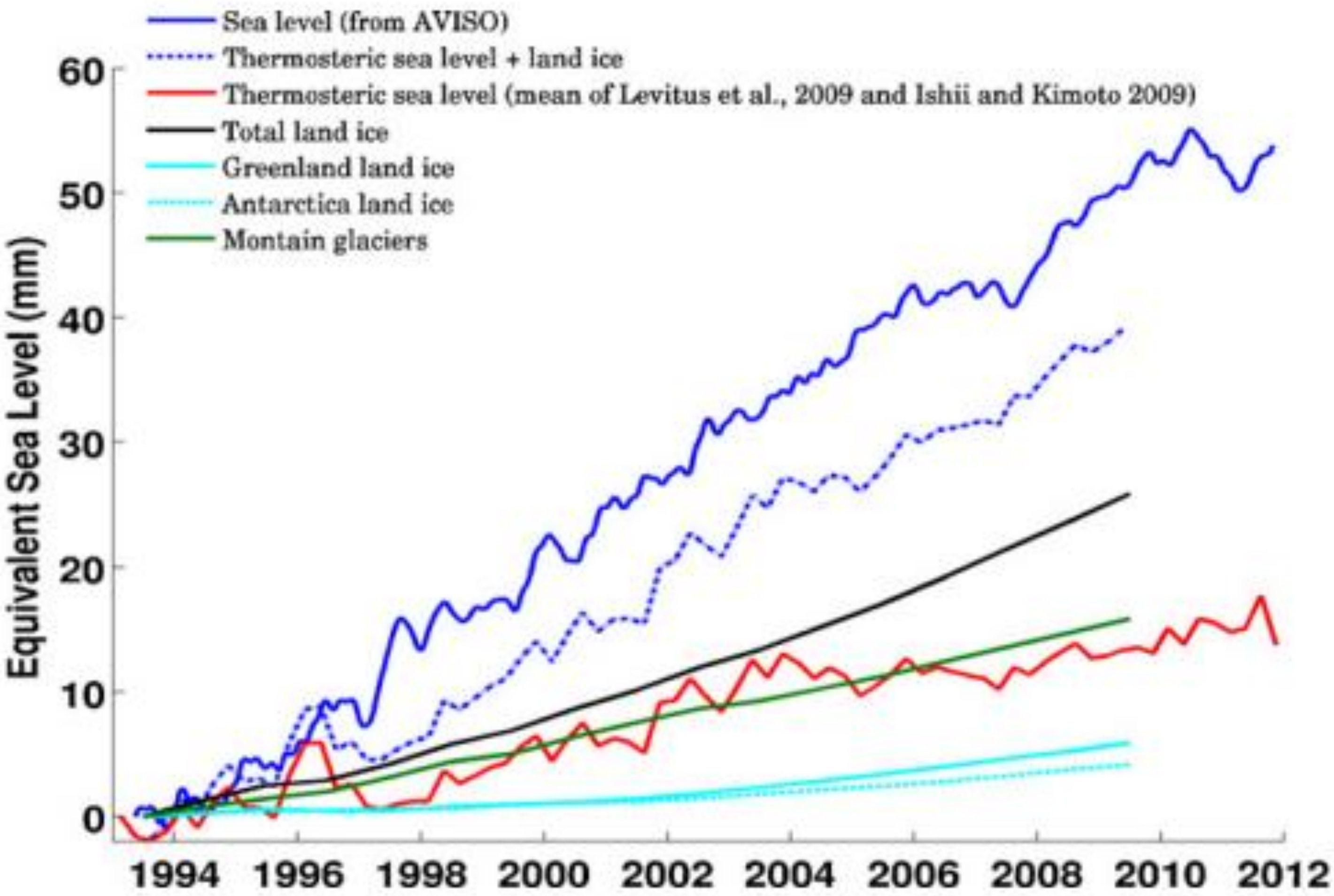
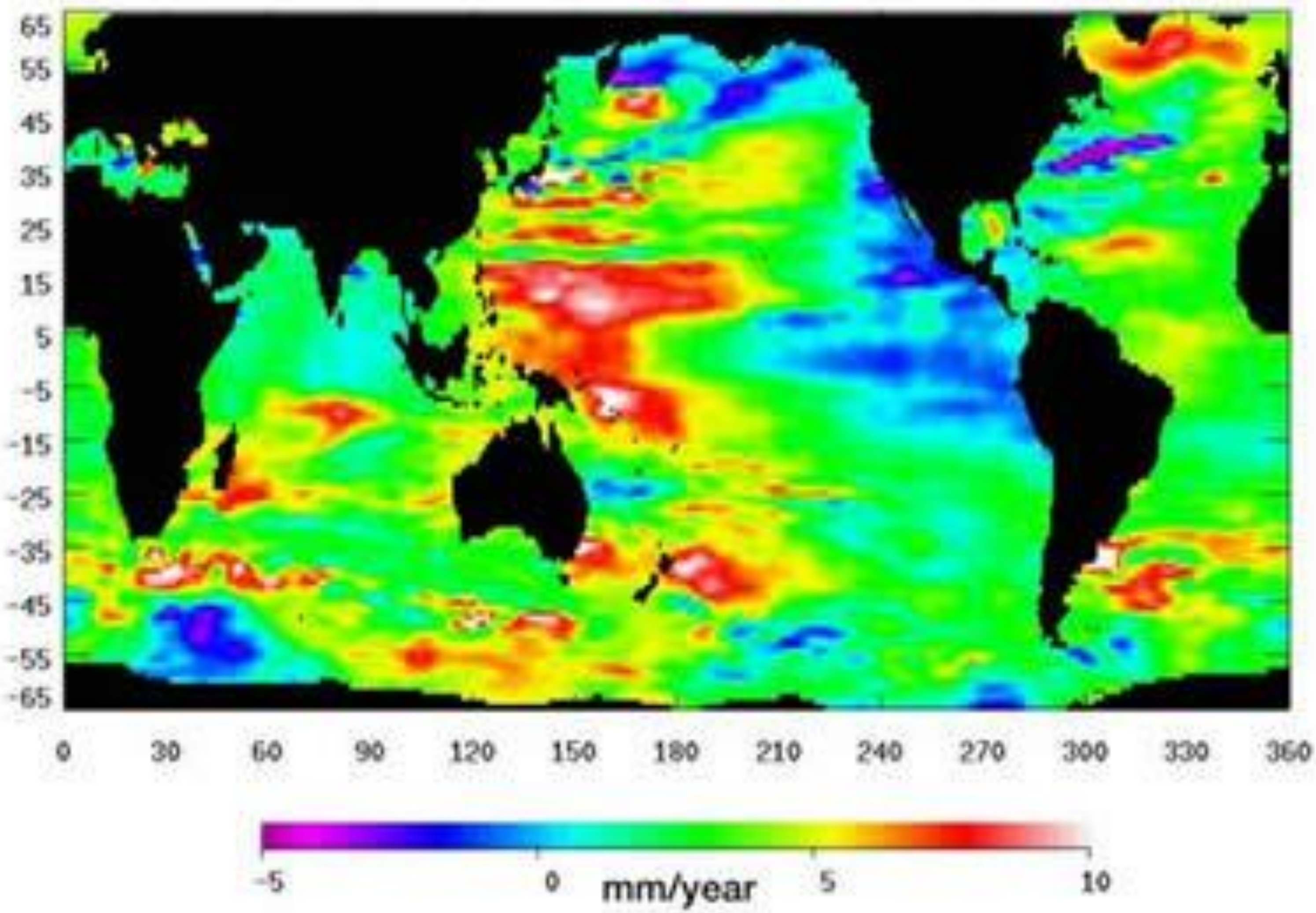
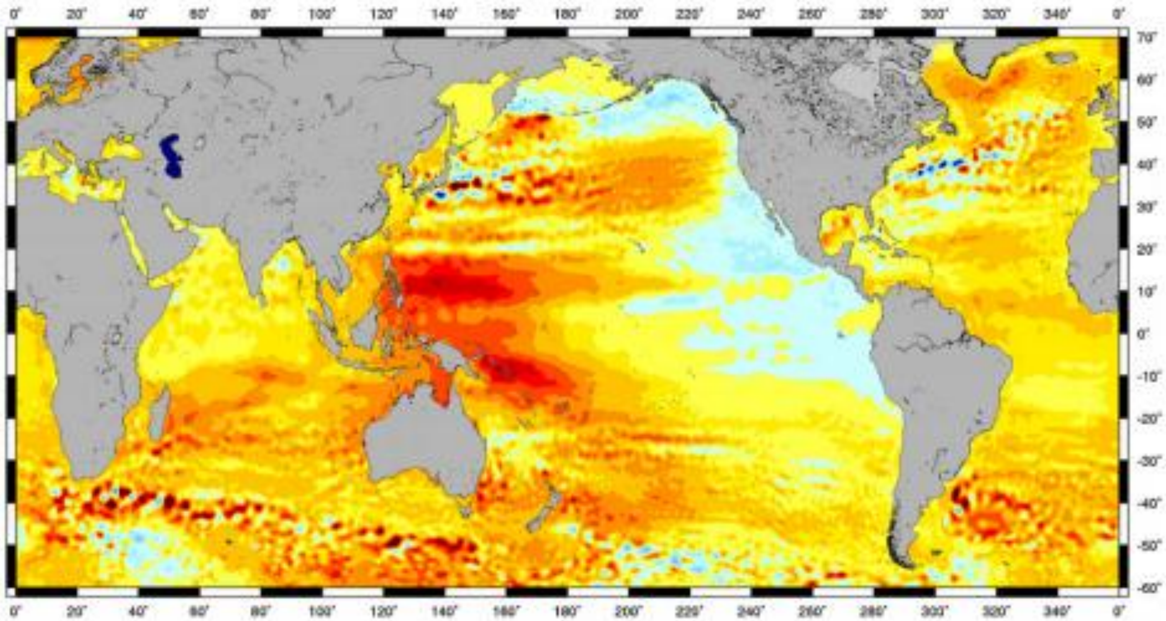


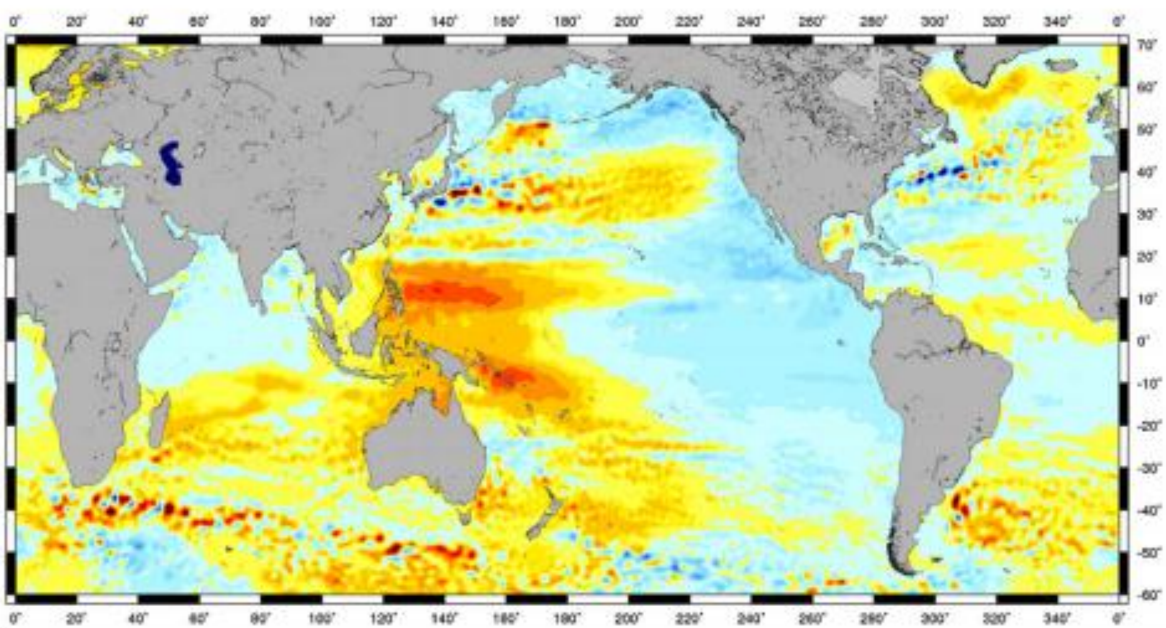
Fig. 6. Observed sea level from satellite altimetry over 1993–2010 (blue solid curve). Thermal expansion (red curve; mean value based on temperature data from Levitus et al., 2009; Ishii and Kimoto, 2009). Contribution from Greenland and Antarctica (cyan curves) and glaciers (green curve). The black curve represents the total land ice contribution while the blue dotted curve represents the total climatic contribution (sum of thermal expansion and land ice) (updated from Cazenave and Llovel, 2010).

Trend of Sea Level Change (1993-2008)





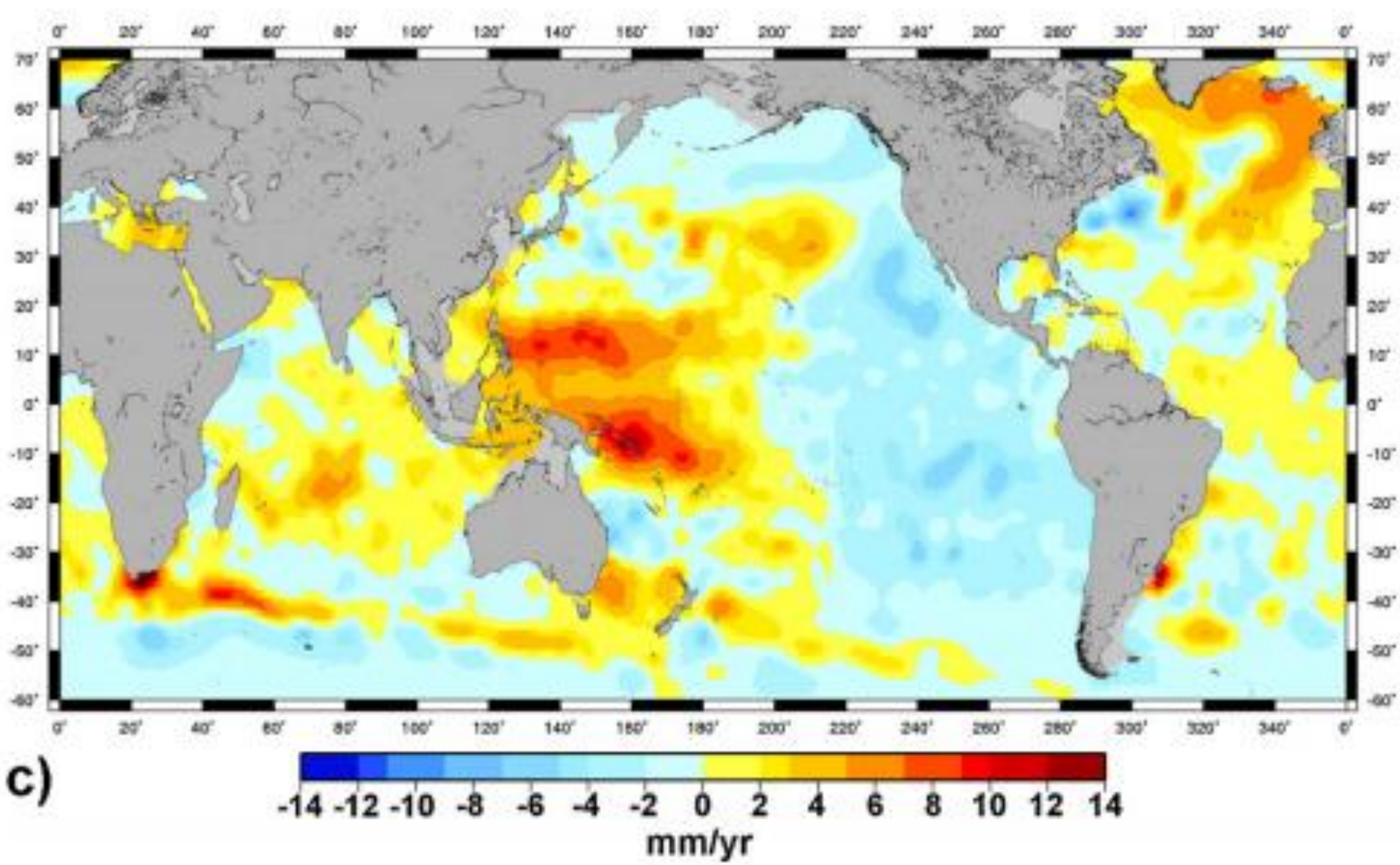
a)



b)

(a) **spatial trend patterns in sea level from satellite altimetry data over 1993–2010.**

(a) **(b) Spatial trend patterns in sea level from satellite altimetry data over 1993–2010 but with the global mean trend of 3.2 mm/yr removed.**



(c) Spatial trend patterns in thermosteric sea level over 1992–2010. (data from Levitus et al., 2009) (global mean trend removed).

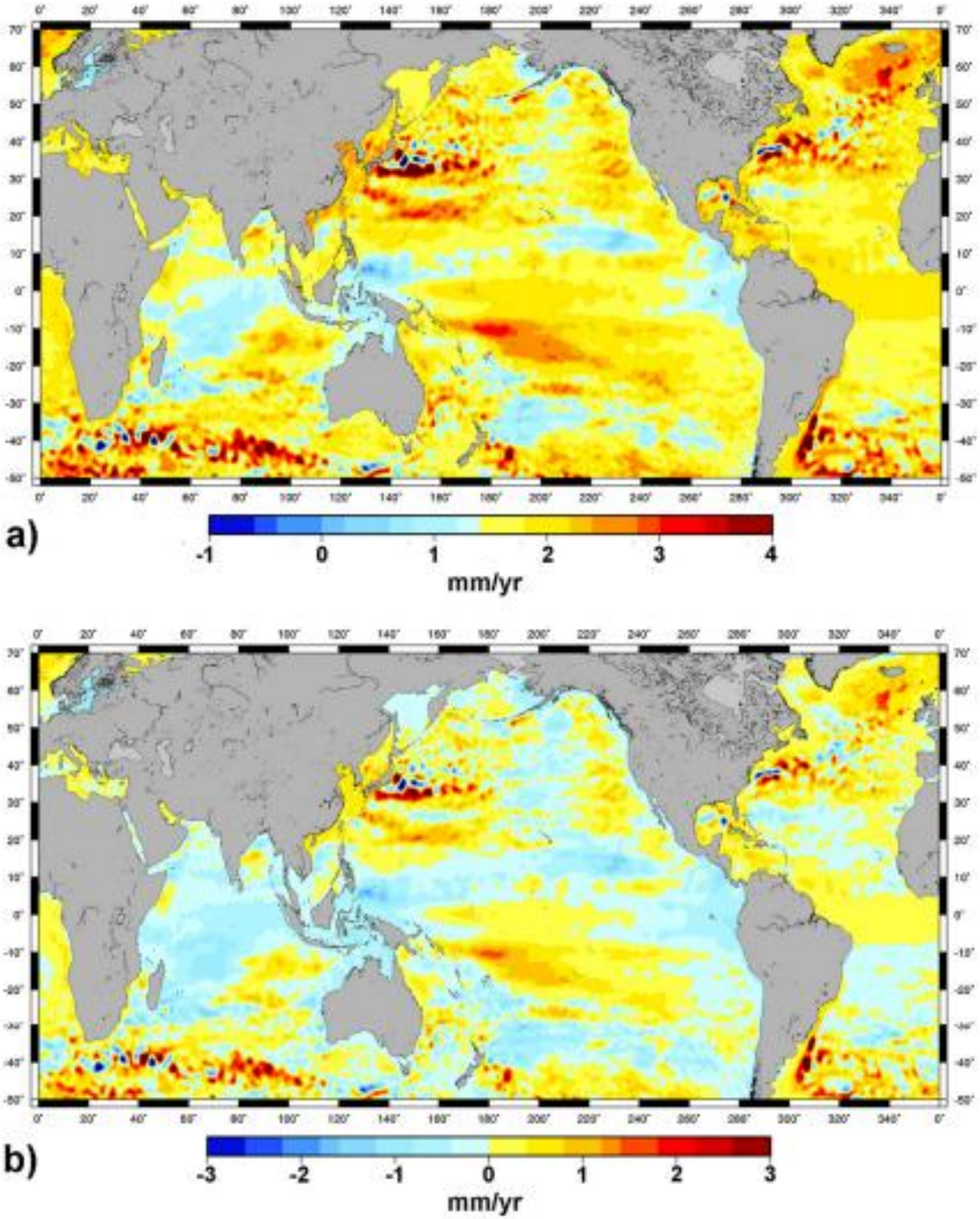


Fig. 9. (a) Spatial trend patterns in sea level over 1950–2009 from Meyssignac et al. (in press-a) reconstruction.

(b) Spatial trend patterns in reconstructed sea level over 1950–2009 but with the global mean trend of 1.8 mm/yr removed

SEA-LEVEL INDICATORS – in order to study sea level changes

1. Elevation and age relationships: raised marine deposits and landforms in glaciated areas. Examples based on Canadian Arctic data - J.T. Andrews
2. Sea-level markers in coastal barrier sands: examples from the North Sea coast - B. Roep
3. Marine molluscs as indicators of former **sea-level** stands - K.S. Petersen
4. Beachrock as a sea-level indicator - D. Hopley
5. Ooids as sea-level indicators - L.R. Kump and A.C. Hine
6. Corals and reefs as indicators of paleo-sea levels, with special reference to the Great Barrier Reef - D. Hopley

8. Coralline algae as indicators of sea-level - W.II. Adey
9. Vermetid gastropods as sea-level indicators - J. Laborel
10. The diagenetic products of marine carbonates as sea-level indicators - J. Coudray and L. Montaggioni
11. Marine notches - P.A. Pirazzoli
12. Submerged forests as sea-level indicators - A. Hoyworth
13. Analysis of botanical macro-remains - K.-E. Behre
14. Foraminifera as sea-level indicators - D.B. Scott and F.S. Medioli

15. Diatoms as indicators of sea-level change - A.J.M. Palmer and W.H. Abbott
16. Ostracode options in sea-level studies - D. van Harten
17. Shell middens as a source for additional information in Holocene shoreline and sea-level reconstruction: examples from the coast of Brazil - L. Martin, K. Suguio and J.-M. Flexor

AGE

1. Radiocarbon dating - W.G. Mook and 0. van de Plassche
2. Dendrochronological dating - A. Heyworth

ALTITUDE

1. Determination of altitude - W.G. Jardine

Exposed rock surfaces (granitic tors) at Badungala, 69 km on the Colombo – Galle Road, West Coast of Sri Lanka depict the palaeo climate changes.

A beach rock reef patch at Chilaw (Northwestern coast) formed due to the sea level changes during the Holocene Epoch.

[RADIOCARBON, VOL 30, NO. 1, 1988, P 125–128]

HIROSHIMA UNIVERSITY RADIOCARBON DATES I
WEST AND SOUTH COASTS OF SRI LANKA*

JINADASA KATUPOTHA**

Department of Geography, Hiroshima University, 1-1-89, Higashi Senda Machi, Naka-ku, Hiroshima 730, Japan

The following list reports radiocarbon dates of geologic samples collected from the west, southwest and south coasts of Sri Lanka during August 1985. The tidal range on Sri Lanka coasts is very small, the lowest neap at −0.48m and highest spring at +0.52m from msl (data based on the standard point of Colombo, datum level 0.38m below msl).

Radiocarbon age measurements were carried out at the Department of Geography, Hiroshima University Radiocarbon Dating Laboratory. The dates were obtained by liquid scintillation counting of methanol using a laboratory procedure (Fujiwara & Nakata, 1984). All coral, shell, and calcareous algae samples were treated in 10% HCl, and pure $CaCO_3$ samples were converted into methanol. Dates are correlated with the chronology of the Holocene epoch (Fairbridge, 1968).

The results are expressed in radiocarbon years relative to AD 1950 based on the Libby half-life of 5568 ± 30 years, using new NBS oxalic acid standard (SRM 4900C) as "modern" (Stuiver, 1983).

[RADIOCARBON, Vol. 30, No. 3, 1988, P 341-346]

HIROSHIMA UNIVERSITY RADIOCARBON DATES II
WEST AND SOUTH COASTS OF SRI LANKA

JINADASA KATUPOTHA*

Department of Geography, Hiroshima University,
1-1-89, Higashi Senda Machi, Naka-ku,
Hiroshima 730, Japan

INTRODUCTION

Geologic samples for 14C age measurements were collected from the west, southwest and south coasts of Sri Lanka during October and November 1986. Sample points were leveled based on the Colombo datum level. Results presented below were obtained by liquid scintillation counting of methanol for coral and shell samples. Ages were measured from December 1986 to May 1987, at the Department of Geography, Hiroshima University, Radiocarbon Dating Laboratory, using the laboratory procedure described
by Fujiwara and Nakata (1984).

Sample preparation techniques were similar to those mentioned in the first list (Katupotha, 1988). The results are expressed in radiocarbon years relative to AD 1950 based on the Libby half-life of 5568 ± 30 years, using the new oxalic acid standard (SRM 49000) as `modern' (Stuiver, 1983).

The tidal range on Sri Lanka coasts is small, ranging from the mean low water spring (MLWS) at -37cm to mean high water spring (MHWS) at +40cm from the mean sea level (MSL) (data based on the standard point of Colombo, datum level 38cm below MSL. Tide tables, vol 2, Pacific and Indian Oceans, 1982).

However, high waves (height 5m or more) are seen along the southwest and south coasts and are related to the strong southwest monsoon season from May to September. The present living corals thrive from MLWS to 8m and 4m in depth in fringing reef and lagoon reef areas at Hikkaduwa, respectively (Mergner & Scheer,1974).

HR-264. Hatagala (Hungama) 4440 ± 60

Shell (Veneridae) from exposed deposits, Hambantota dist (6° 06' 35“ N, 80° 56' 50" E), elev 80cm above msl. Comment: shells gathered in lagoon floors and were deposited in situ following coastal progradation since Late Subboreal. Sample subm by N P Wijayananda.

HR-265. Kalametiya 3570 ± 60

Shell (Veneridae) from exposed shell deposit, Hambantota dist (6° 05‘ 08" N, 80° 56' 45" E) elev 1.1 Om above msl. Comment: shell was composed mainly of coarse sand and calcareous clay.

HR-266. Kalametiya 4460 ± 60

Shell (Veneridae) from exposed shell deposit (6° 05' 15" N, 80° 57' 08“ E), elev 2.2m above msl. Comment: shells were embedded in black-to-blueblack mud and clay; it is assumed that HR-265 and -266 gathered (in situ?) in lagoon floors following coastal progradation since Late Subboreal.

As for deposition pattern and composition of shell deposits in Hambantota dist, shells probably accumulated at rims of emerged coastal embayments or lagoon floors by three processes:

1) bulk of valves piled up by wave action on rims of coastal embayments following coastal progradation since Late Holocene (Late Subboreal);
2) shells gathered in lagoon floors of marine or brackish pools, and they were deposited (in situ?) since Late Subboreal;
3) shells on coastal hills and dunes left by early inhabitants during daily activities.

These and previous dates (Katupotha, 1988) indicate that sea level was at least 1.Om or higher than present msl, from mid-Holocene (Main Atlantic) to Late Holocene (Early Subatlantic), with minor oscillations. It is assumed that local palaeo-sea level was not lower than at present during above-mentioned period.

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

JINADASA KATUPOTHA[1] and KENZO FUJIWARA

Department of Geography, Hiroshima University, 1-1-89, Higashi Senda Machi, Naka-ku, Hiroshima 730 (Japan)

(Received November 11, 1987; revised and accepted March 25, 1988)

Abstract

Katupotha, J. and Fujiwara, K., 1988. Holocene sea level change on the southwest and south coasts of Sri Lanka. Palaeogeogr., Palaeoclimatol., Palaeoecol., 68: 189–203.

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

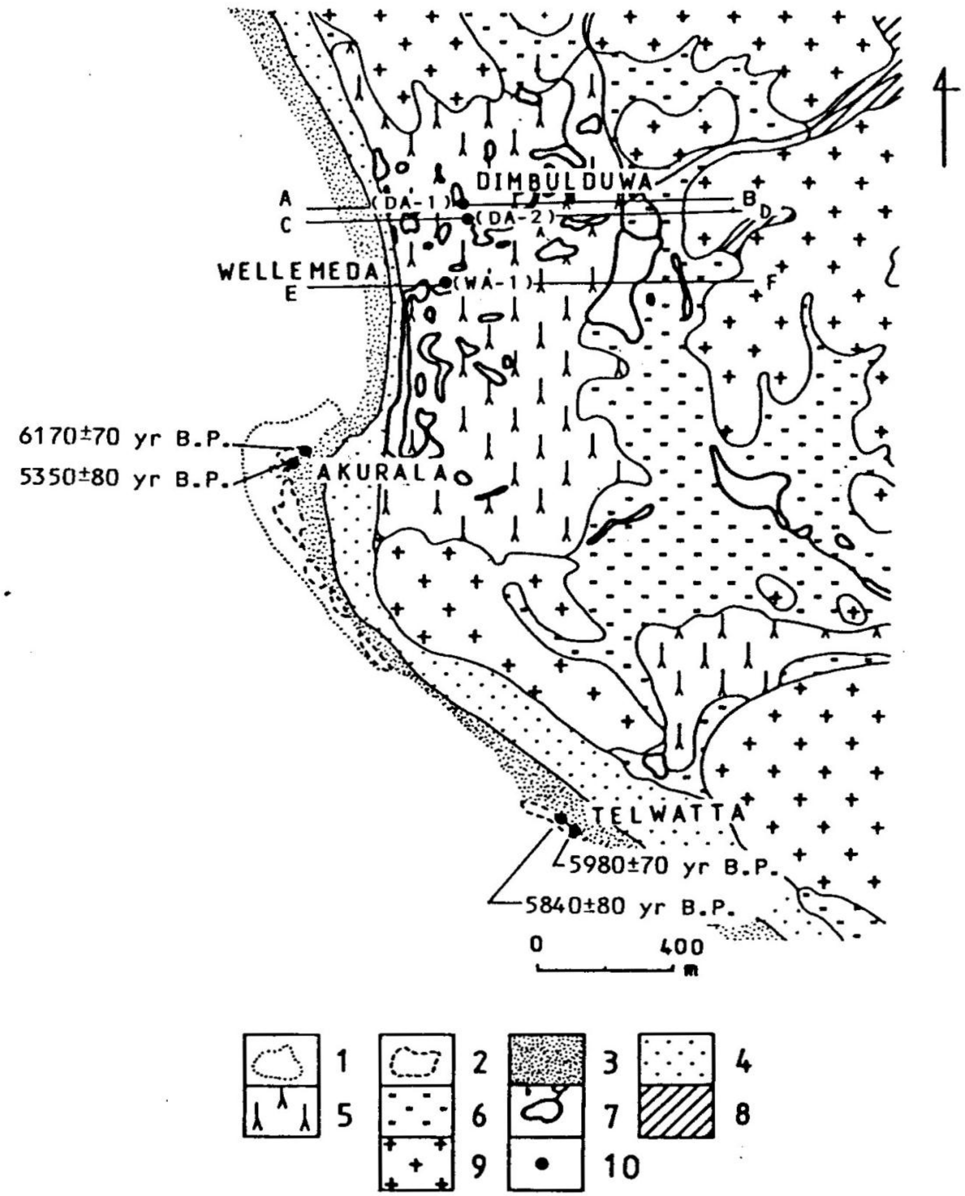


Fig.3. Landforms map showing buried and emerged coral deposits at Akurala and Akurala-Telwatta. Cross-sections are referred to in Fig.4. *1* = Inter-tidal reef patch. *2* = Emerged reef patch. *3* = Foreshore. *4* = Beach ridge. *5* = Mangrove swamp. *6* = Marsh. *7* = Water hole, lake and stream. *8*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

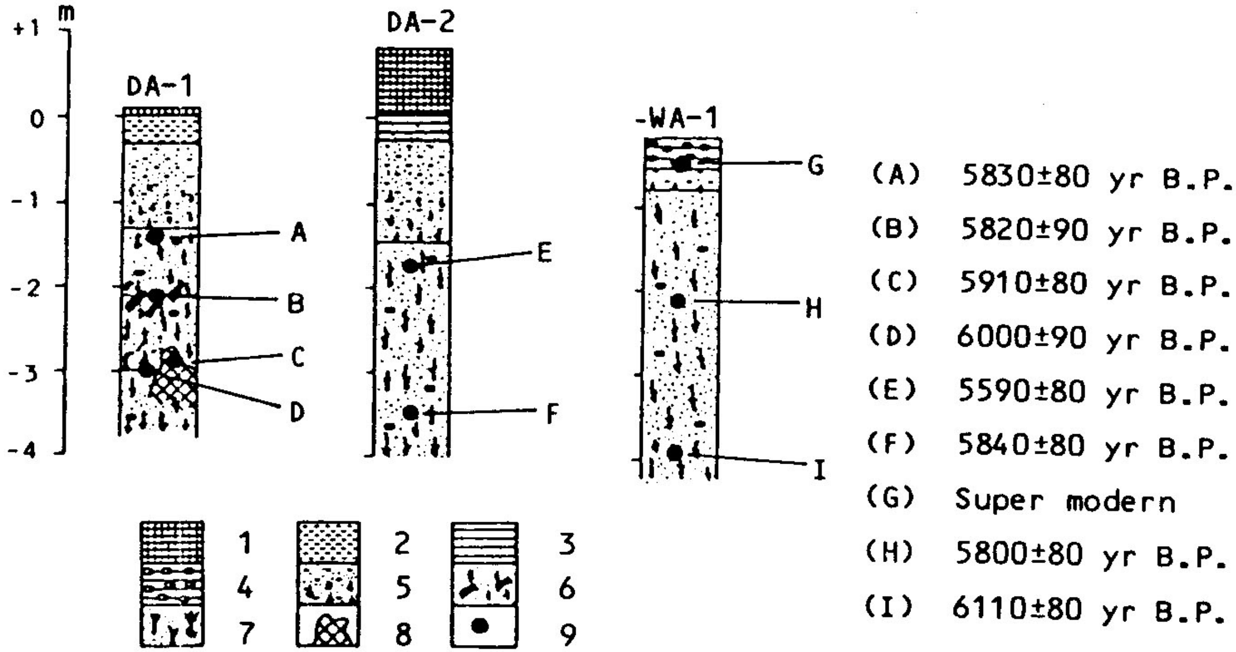


Fig.4. Cross-sections, stratigraphic and radiocarbon age datings of three coral quarries at Akurala. ^{14}C dates are referred to in Table I. *DA-1* = Dimbulduwa-Akurala; *DA-2* = Dimbulduwa-Akurala; *WA-1* = Wellemeda-Akurala. *a* = Beach ridge. *b* = Mangrove swamp. *c* = Water hole, lake and stream.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

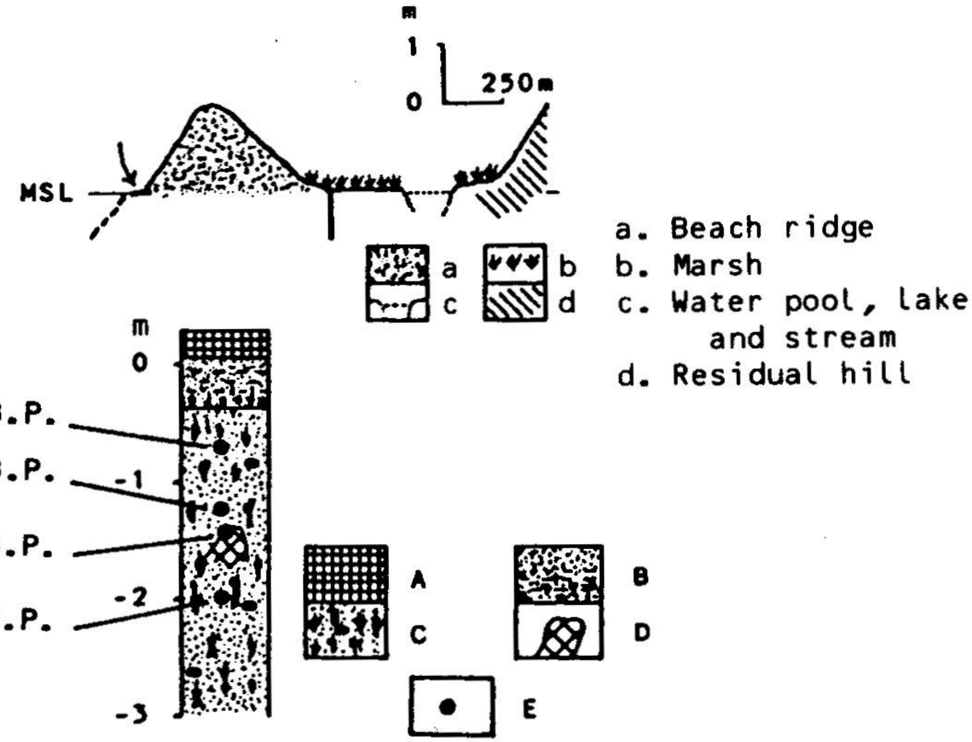


Fig.6. Map showing landforms of the Mihiripenna area. ^{14}C dates of samples from a coral quarry are referred to in Table I. *1* = Inter-tidal reef patch. *2* = Foreshore. *3* = Beach ridge. *4* = Marsh. *5* = Water hole, lake and stream. *6* = Flood or valley plain. *7* = Residual hill and ridge. *8*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

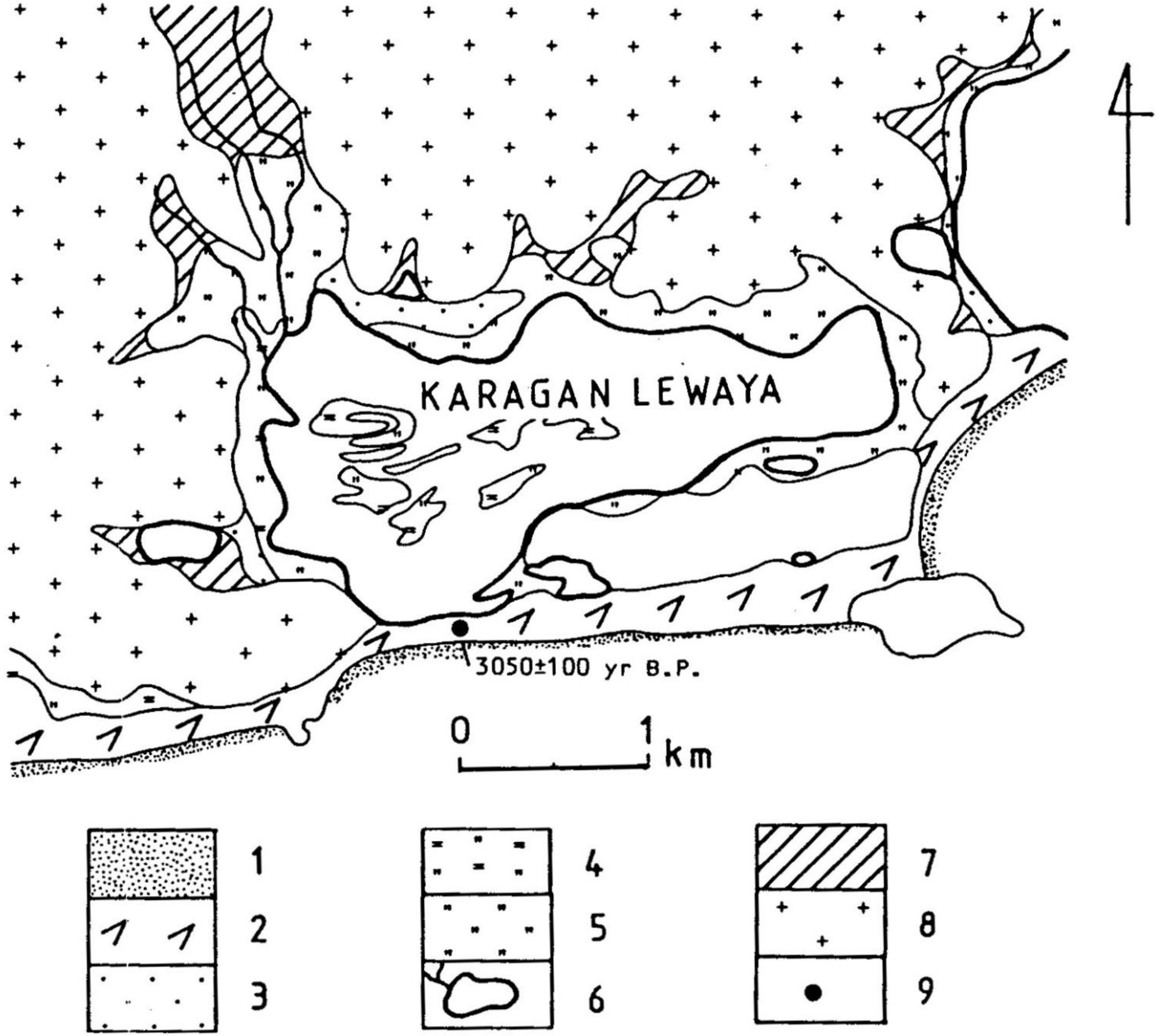
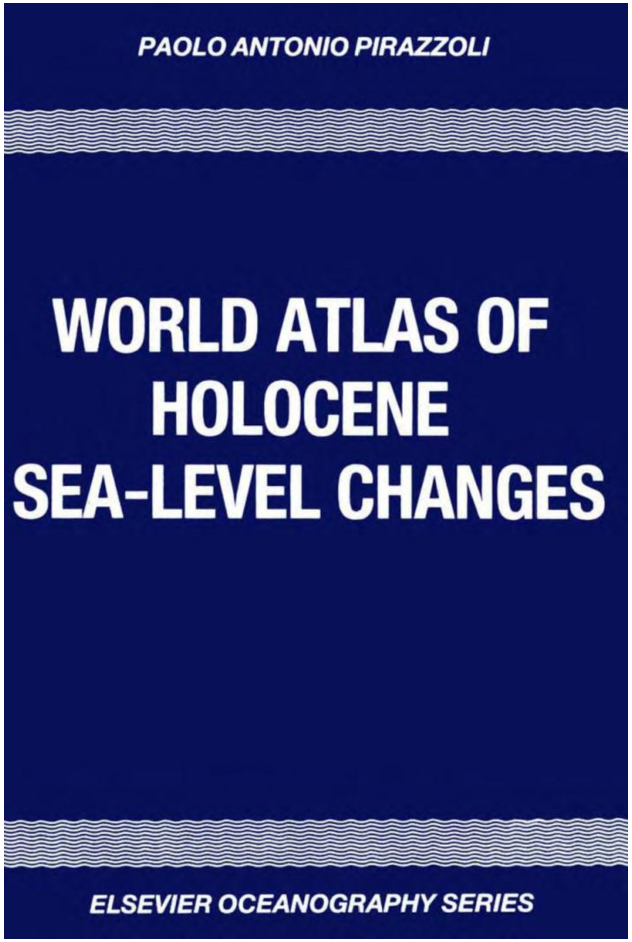


Fig.9. Landforms map around Karagan Lewaya (lake). ^{14}C date of a sample from a shell midden is referred to in Table I. *1*=Foreshore. *2*=Sand dune. *3*=Beachridge. *4*=Marsh and wasteland. *5*=Wasteland. *6*=Water hole, lake and stream. *7*=Flood or valley plain. *8*=Residual hill and ridge. *9*=Sample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



On the south coast of Sri Lanka, an accurate relative MSL curve J, deduced from slightly emerged corals collected in growth position, was produced by Katupotha and Fujiwara (1988); it shows a sealevel stand between l and 2 m above present from 6000 to 2000 yr BP .

In conclusion, most coastal areas in the west Indian Ocean have not yet been systematically studied. The few sea-level curves available indicate that slight emergence predominated during the late Holocene along the coasts of Mozambique, on the southern shores of the Persian Gulf, west India and south Sri Lanka, whereas evidence of emergence is missing in oceanic islands (Rkunion, Maurice). In the east part of the Indian Ocean, on the other hand, slight Holocene emergence (at least 0.5 m since about 3000 yr BP) was reported from the *COCOS (Keeling) Islands by* Woodroffe et al. (1990).

Chronology of Inland Shell Deposits on the Southern Coast of Sri Lanka

JINADASA KATUPOTHA

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

AND

N. P. WIJAYANANDA[1]

Oceanographic Unit, National Aquatic Resources Agency, Crow Island, Mattakkuliya, Colombo 15, Sri Lanka

Received February 22, 1988

Extensive patches of fossil shell deposits are found in many places along the rims of emerged coastal embayments and lagoon floors on the southern coast of Sri Lanka. Compositional and depositional sequences of fossil shells (Veneridae, Cerithidae, and Nassaridae) reveal that the bulk of the valves has been accumulated by three processes: (a) the shells have been piled up on the rims of emerged coastal embayments mainly by wave action; (b) following coastal progradation since the late Subboreal the shells possibly gathered on lagoon floors; and (c) the valves on the coastal hilly areas and dune areas were discarded by early human inhabitants in the course of their daily activities. Radiocarbon dates of fossil corals along the southwest and south coasts support this interpretation and indicate that mean sea level was at least 1 m higher than present in the middle Holocene. The fossil species may have lived in an intertidal zone of embayments and lagoons that extended 3 km or more inland form the present shore in the middle Holocene.

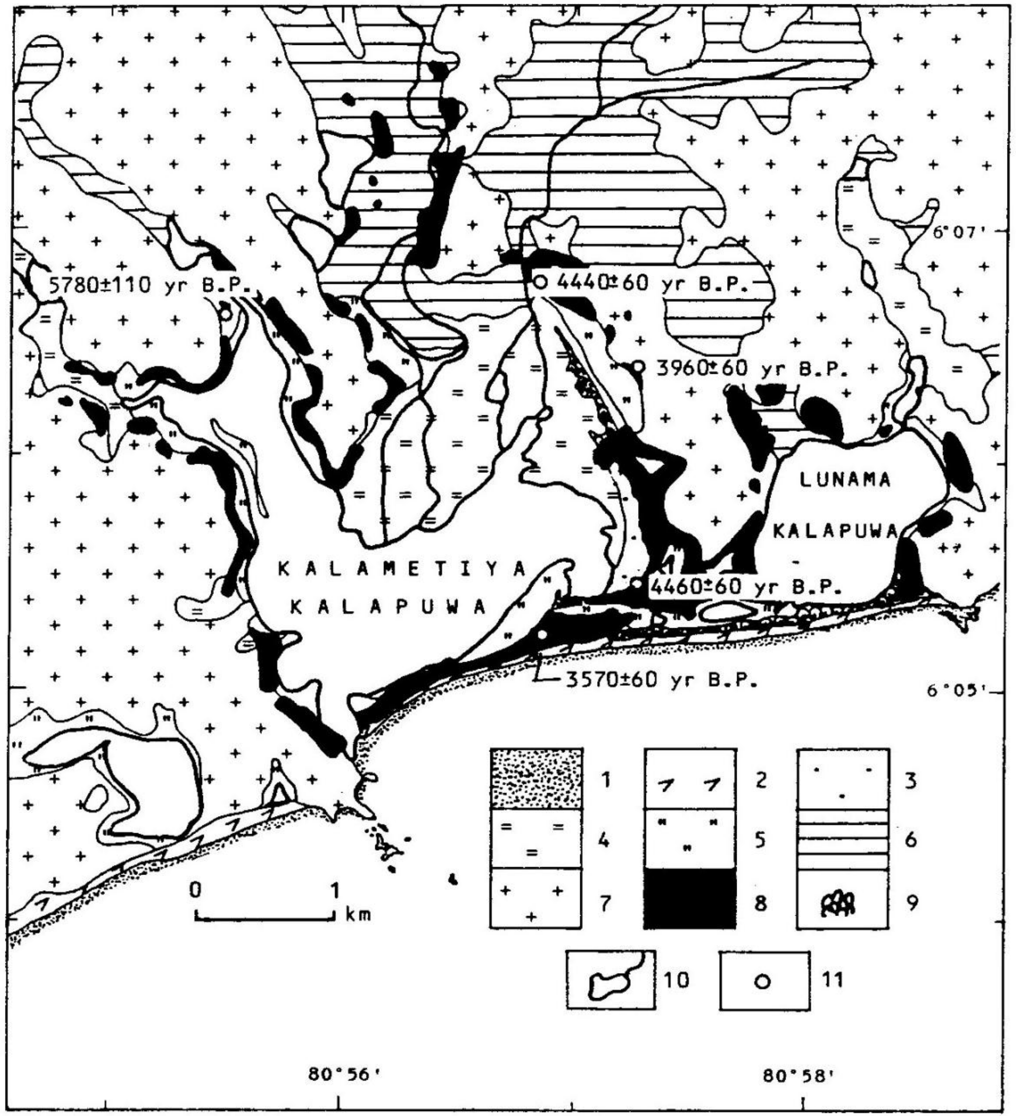


FIG. 2. Map showing landforms of Kalametiya area. ^{14}C dates of shell deposits are referred to in Table 1. (1) Foreshore; (2) sand dune; (3) beachridge; (4) marsh; (5) wasteland; (6) flood or valley plain; (7) residual hill and ridge; (8) emerged shell deposits; (9) mangrove swamp (10) water hole, lake, and stream; (11) sample location.

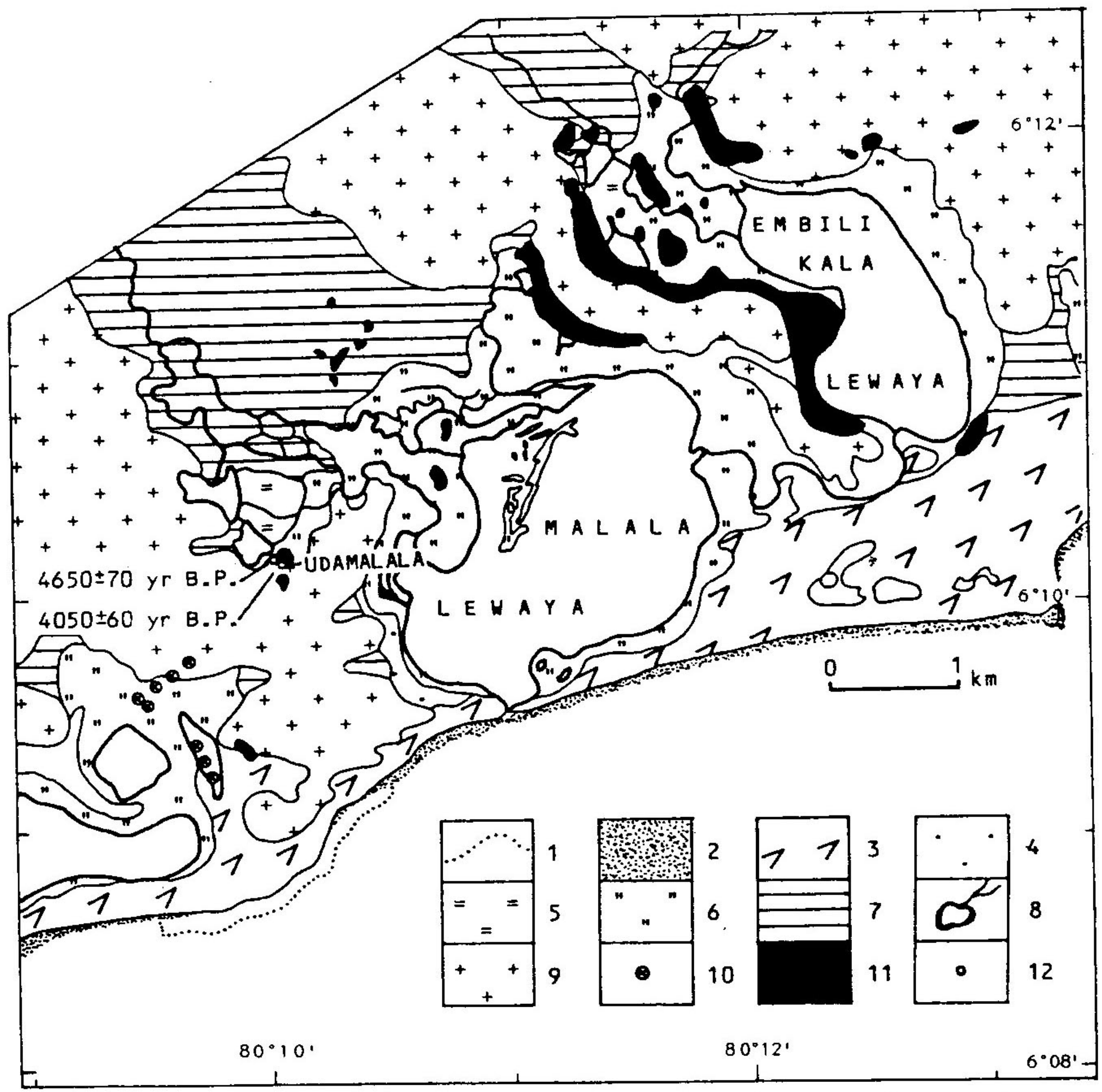


FIG. 3. Map showing the landforms of the Malala Lewaya area. ^{14}C dates of samples from two shell deposits are referred to in Table 1. (1) Intertidal reef patch; (2) foreshore; (3) sand dune; (4) beachridge; (5) marsh; (6) wasteland; (7) flood or valley plain; (8) water hole, lake, and stream; (9) residual hill and ridge; (10) small patches of emerged shell deposits; (11) extensive shell deposits; (12) sample location.

Journal of the Geological Society of Sri Lanka, Vol. 5 (1994) 141-152, Printed in Sri Lanka.

Quaternary Research in Sri Lanka

Jinadasa Katupotha

Department of Geography, University of Sri Jayawardenapura, Gangodawila, Nugegoda, Sri Lanka.

ABSTRACT

Quaternary is the era which saw the appearance of mankind. There is disagreement over the duration, with some scientists retaining a short-time scale (600,000 years) while a majority accepting the long time-scale of 1.8 to 2.0 million years. It comprises two epochs - the Pleistocene and the Holocene. The Pleistocene epoch in Sri Lanka has been subdivided based on different types of fossils. These subdivisions are useful in the study of palaeomagnetic changes, geological formations and palaeolithic cultures in Sri Lanka. Radiometric dating of fossil coral and shells collected from the western and southern coastal zone suggested mid and late Holocene three high sea-level episodes between 6,240 and 2,270 yr B.P. However, there is a need for further investigations on the whole Quaternary period by different disciplines in order to reveal the nature of the palaeogeography, palaeoclimatology and palaeoecology of Sri Lanka.

TABLE 1. Subdivisions of the Quaternary in the Main Glacial Areas.

	ABSOLUTE DATING	PROVISIONAL NUMERICAL ORDER	NORTH AMERICA	ALPS	NORTH EUROPE	SRI LANKA
	Present					
H	-					
	10,3000					
	10,300 -		LATE			
	17,000		WISCONSIN	Late Wurm		
	17,000 -		MAIN			
	30,000		WISCONSIN	Main Wurm		
LP	30,000-	Main				
	50,000	Interglacial				
	50,000 -	Last Glaciation	WISCONSIN	Early Wurm	Weichselian	Normal 6
	75,000					Humid 6
	67,000 -	Last -	Sangamanian	Uznach	Eemian	Normal5
	128,000	Interglacial				Humid 5
	128,000 -	Forth Glaciation	ILLINOIAN	RISS II	WARTHE	Humid 4
	180,000			RISS I	SAALE	
	180,000	Third -	Yarmouth	Hotting	Holstein	Normal3
MP	230,000	Interglacial				
	230,000 -	Third Glaciation	KANSAN	MINDAL	ELSTER	Humid 3
	300,000					
	300,000 -	Second -	Aftonian			Normal2
	330,000	Interglacial				
	330,000 -	Second -	NEBRASKAN	GUNZ	PRE-ELSTER	Humid 2
	470,000	Glaciation				
	470,000 -				Waalian	Normal 1
	538,000					
	538,000 -	First -	PRE -	DONAU II	WEYBOURNE	Humid 1
	548,000	Glaciation	NEBRASCAN			
EP	548,000 -				Tiglian	
	585,000					
	585,000 -			DONAU I	RED CRAG	
	600,000					
	c 600,000 -			Villa frannuchian		
	2,000,000					

NOTE: Named interglacials are underlined. Source: Fairbridge 1968; H - Holocene, LP - Late Pleistocene, MP - Middle Pleistocene, EP - Early Pleistoiene.

TABLE 2. Formations and Events in the Cenozoic Era in Sri Lanka

	ERA	SYSTEM	EPOCH	EVENT/FORMATION
PHANEROZOIC	CENOZOIC		Holocene to Present 0.01 m.y	Post-glacial sea level rise, drowning of continental shelf. Younger Group - beach and dune deposits, beachrock, lagoon and estuarine clays, alluvium, buried and emerged coral reefs, beaches, lagoons formed
			Pleistocene 2 m.y.	Marked sea level fluctuations, submergence canyons cut or developed. Older Group - Red Beds, gravels, raised beach and dune deposits, laterite, nodular ironstone
			Pliocene 2 - 5 m.y.	Uplift and erosion
		TERTIARY		
			Miocene 22.5 - 5 m.y	Limestone facies on northwest and north; arenaceous facies on southeast. Tectonic control of sedimentation, with step faulting common. Submergence, separation from India.

Sources: Cooray and Katupotha, 1991; Katupotha, 1988b,c; Swan, 1982.

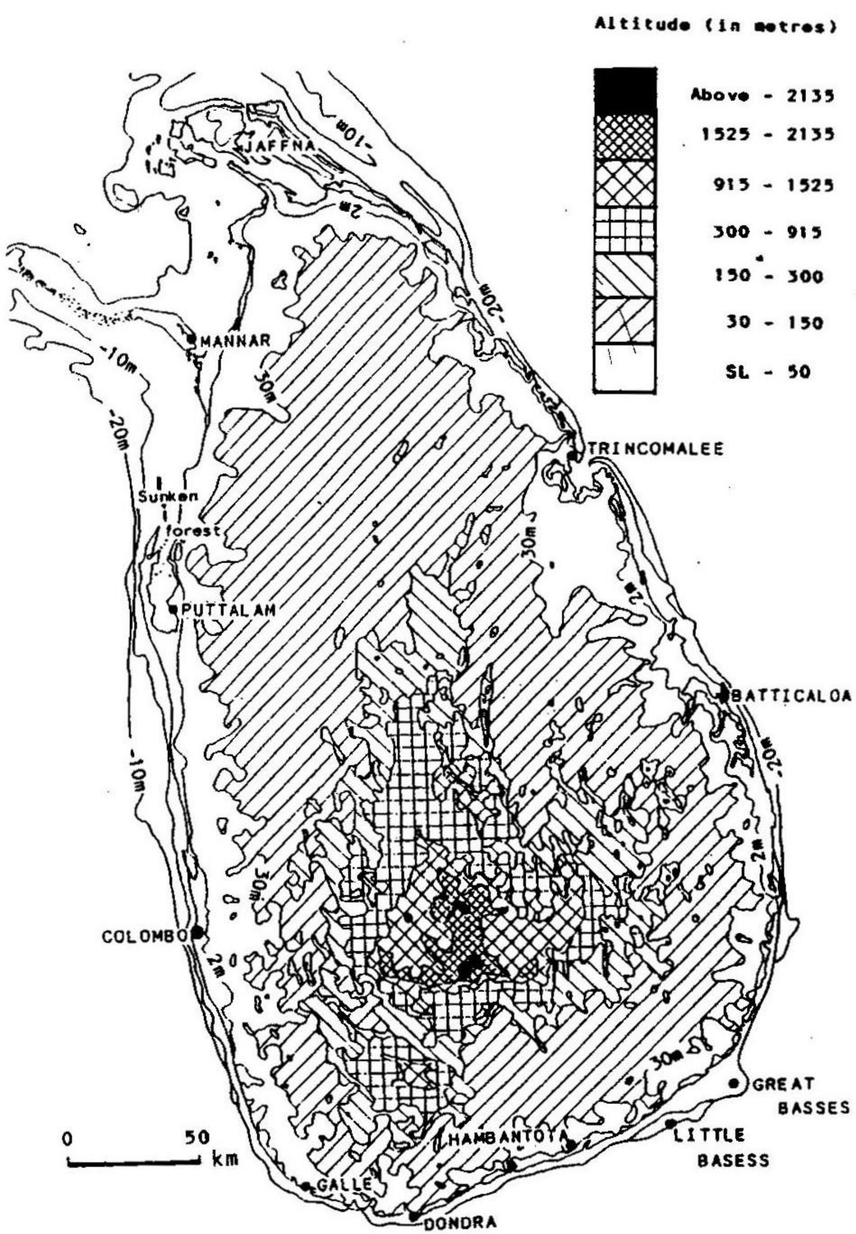


Fig. 1. Oscillations of sea-level between 20 m isobar and the present coastal lowland occurred during the Late Quaternary Period.

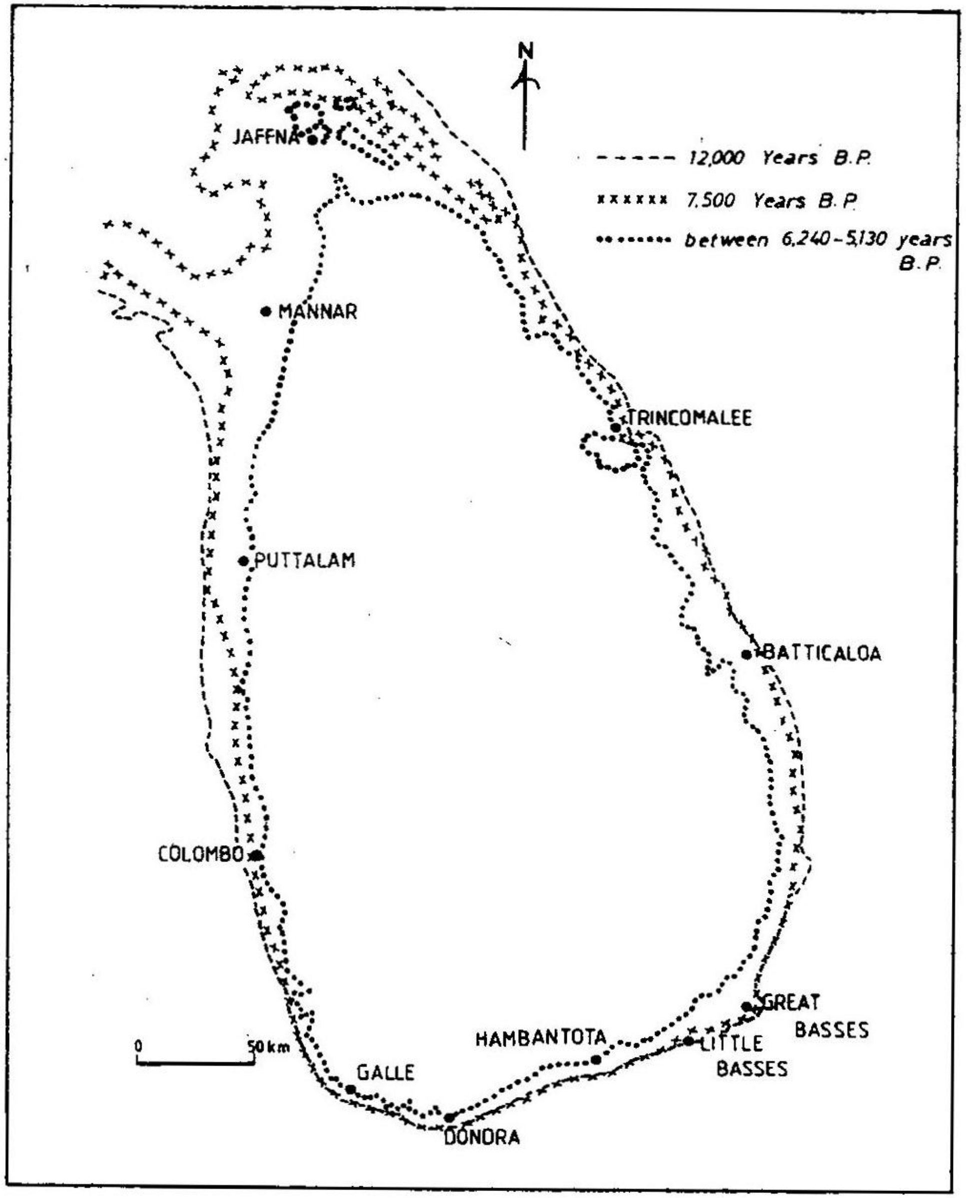


Fig. 4. Possible coastline of Sri Lanka around (i) 12,000 year B.P., (ii) 7,500 years B.P. and (iii) between 6240 and 5130 years B.P.

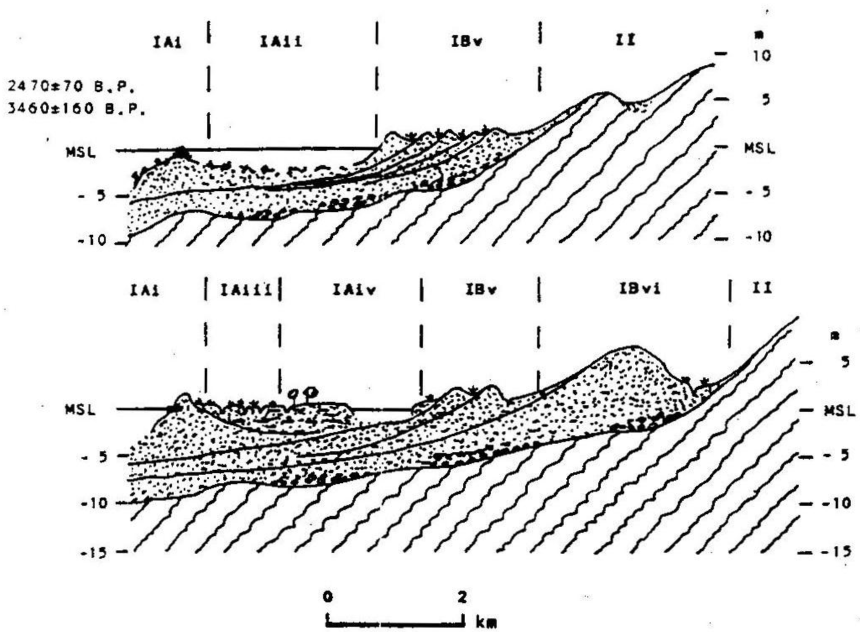


Fig. 5. Generalized sections at Pitipana - Negombo. (IAi) beachrock shoal, (IAii) Barrier Beach, (IAiv) Barrier flats and marshes, (IBv) Old sand ridges, (IBvi) Marshy flats, and (II) Peneplained basement.

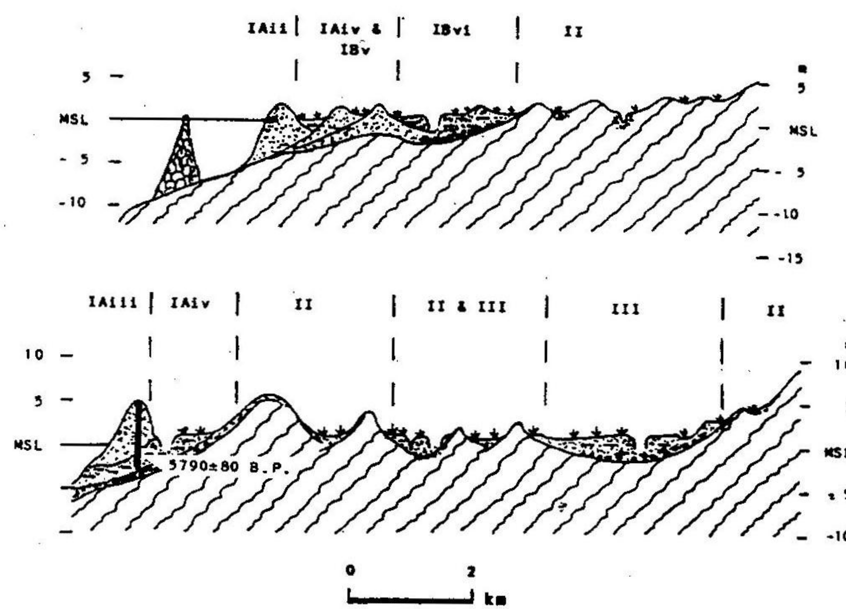


Fig. 6. Generalized sections at Mattakkuliya and Colombo Fort. (IAi) beachrock shoal, (IAii) Barrier Beach, (IAiv) Barrier flats and marshes, (IBv) Old sand ridges, (IBvi) Marshy flats, (II) Peneplaned basement, and (III) Alluvial flood plain.

Handbook on Geology and Mineral Resources of Sri Lanka, K. Dahanayake (ed.), GEOSAS-II, Colombo, Sri Lanka, January 19-24, 1995

Sea-level changes in Sri Lanka

Jinadasa Katupotha

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

ABSTRACT

Coastal materials and landforms are valuable tools in the study of palaeo sea level, climatic and ecologic changes. In Sri Lanka, few researches have been conducted based on such indicators. Different types of deposits and landforms from the continental shelf and coastal lowlands reveal that their formation has followed the coastal transgressions and regressions as well as dry and wet climatic phases during the past 20,000 years.

A segment of an emerged coaral *(in situ)* at Akurala in the Galle District

GEOLOGICAL EVOLUTION OF THE COASTAL ZONE OF SRI LANKA

P.G. Cooray * and J. Katupotha **

* Institute of Fundamental Studies, Kandy, Sri Lanka
** Department of Geography, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

ABSTRACT

Geologically, 90 percent of Sri Lanka is made up of Precambrian (more than 570 mill. years old) crystalline rocks belonging to an ancient, stable part of the earth's crust known as the Indian Shield. This means that since Miocene times (26 mill. years ago) when the northwestern and northern parts of the island were subjected to a major marine transgression, the relative levels of land and sea have remained practically the same. However, minor oscillations of sea level have occurred during post-Miocene times, and it is these changes that have led to the deposition of the Quaternary formation and to changes in the shape of the coastal regions of the Island.

Changes of the relative levels of the land and sea are evidenced by such features as raised beaches, old strandlines, beachrock, inland buried corals and coral reef patches and inland deposits of marine shells. Palaeoclimates have also affected the coastal growth.

Geological formations of the post-Miocene times and the landforms produced by them have also controlled coastal evolution. Coastal growth stages, as shown by the evolution of sand bars, sand spits, lagoons, lakes and marshes along the western coast between Puttalam and Colombo are traced. The northwestern, northern and eastern coasts are prograding ones; coastal erosion and regression are characteristic of the southwestern and northeastern coasts. Hypothetical growth stages in the future are also postulated.

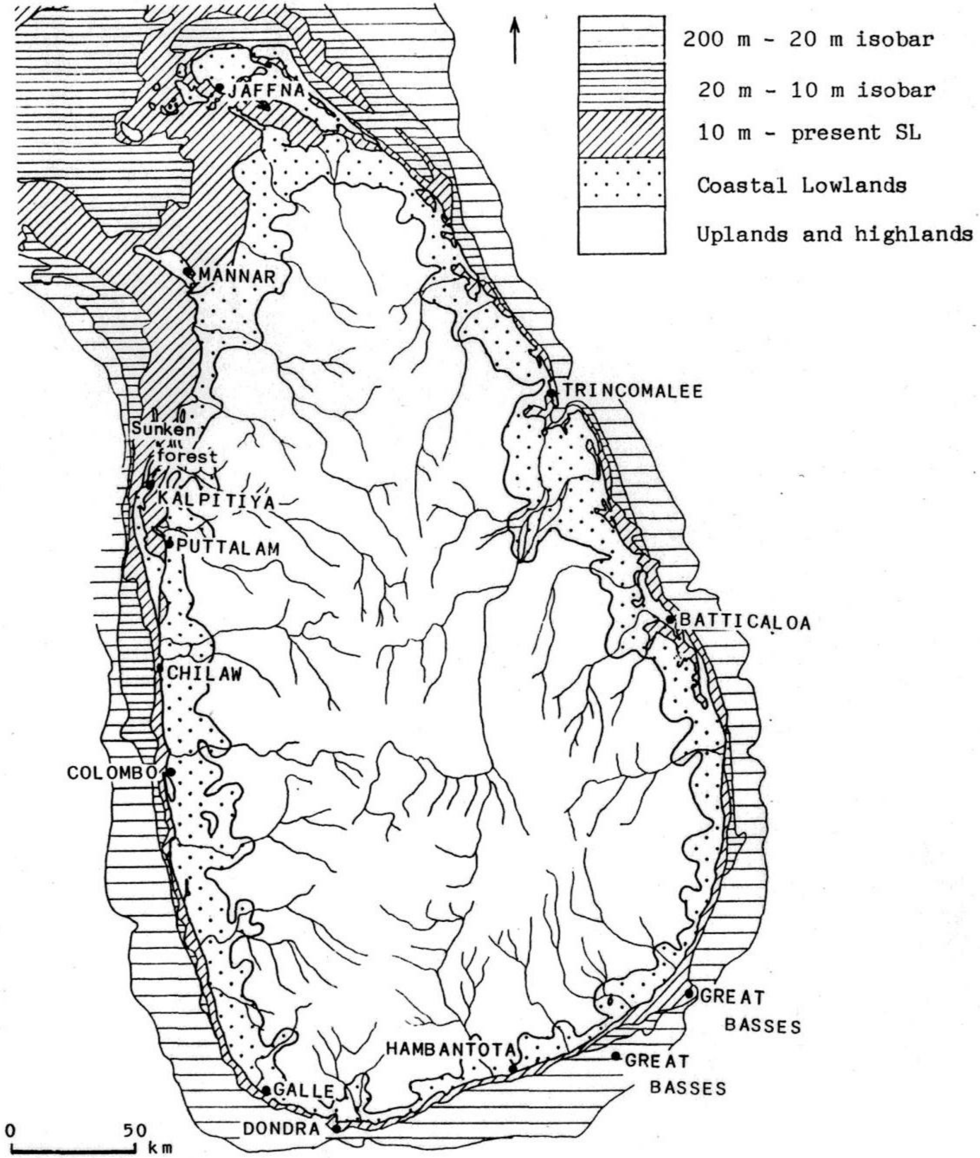


Fig. 1. Oscillation of sea level around Sri Lanka. (1) Evidence of sunken forests, submerged channels of some larger rives and well marked beachrock and coral reefs can be seen between 200m isobar and the present sea level. (2) The coastal lowlands consist of extensive buried coral deposits, emerged coral reef patches, shell deposits and Red Earth (Katupotha, 1988d).

Evidence of Former Sea Level in Sri Lanka

Metres + msl	Types of evidence			Reliability
Positive levels	Marine deposits		Geomorphological	
+ 1.6 - 4.5 + 6.0 - 10.0 + 14.0 - 18.0 + 27.0 - 36.0	shells shell beds beachrock beach deposits		coastal terraces, cut flatforms distributories	high
+ 36.0 - 43.0	---		as above	inconclusive
Negative levels	Stratigraphic		Bathymetric	
+ 0.8 - 24.0	buried valley deposits, bed-rock over bur-dern boundary	crest of beachrock reefs	continental shelf profi-les	high
- 24.0 - 27.0 - 33.0 - 46.0 - 55.0 - 64.0 - 73.0 - 91.0		shelf profiles		Moderate

(Source: Swan, 1964; Cooray and Katupotha - p. 5)

Table 2. Formations and Events in the Cenozoic Era in Sri Lanka (after Swan, 1983)

ERA		SYSTEM	EPOCH	EVENT/FORMATION
PHANEROZOIC	CENOZOIC	Quaternary	Holocene 0.01 m.y. to Present	Post-glacial sea level rise, drowning of continental shelf. **Younger Group** - beach and dune deposits, beachrock, lagoon and estuarine clays, alluvium; raised beaches, lagoons formed.
			Pleistocene 2 m.y.	Marked sea level fluctuations, canyons cut or developed. **Older Group** - Red Beds, gravels, raised beach and dune deposits laterite, nodular ironstone
		TERTIARY	Pliocene 5 - 2 m.y.	Uplift and erosion
			Miocene 22.5 - 5 m.y	Limestone facies on northwest and north; arenaceous facies on northeast. Tectonic control of sedimentation, with step faulting common. Submergence, separation from India.

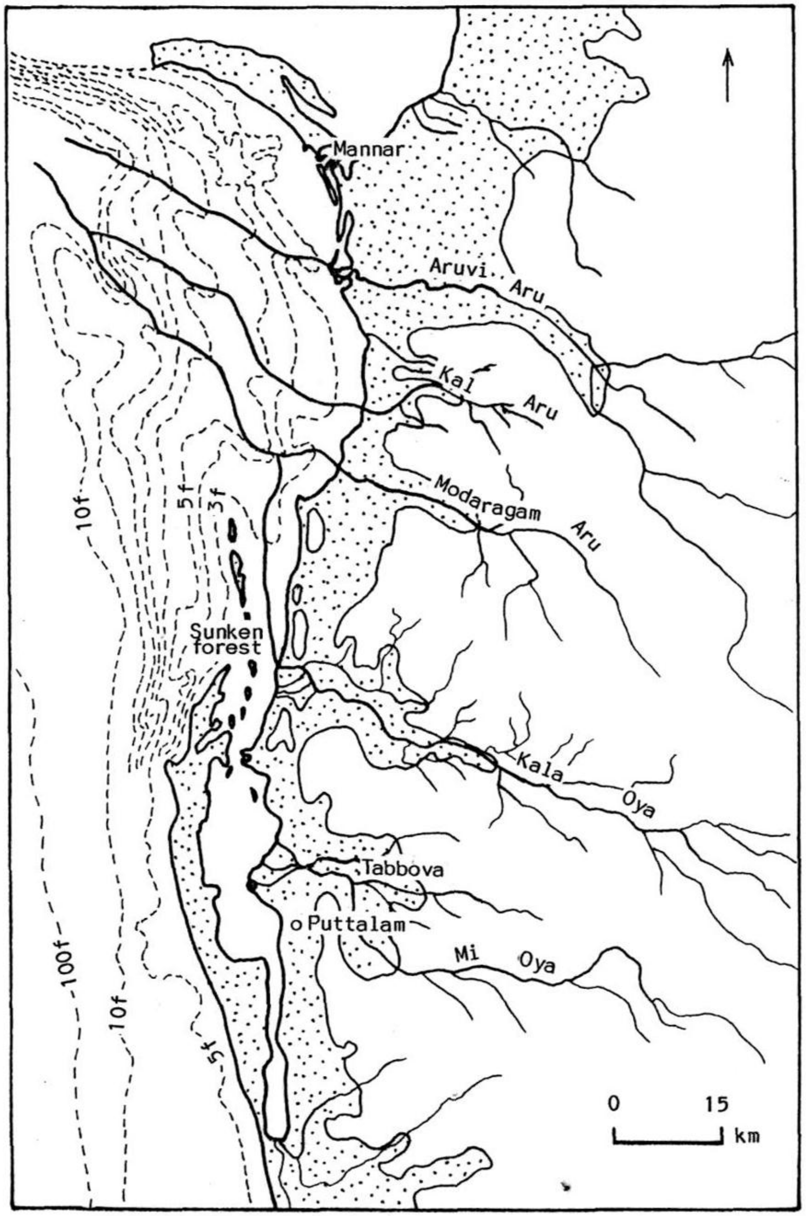


Fig. 2. Submerged river courses on the continental shelf of northwestern of Sri Lanka (After Deraniyagala, 1958).

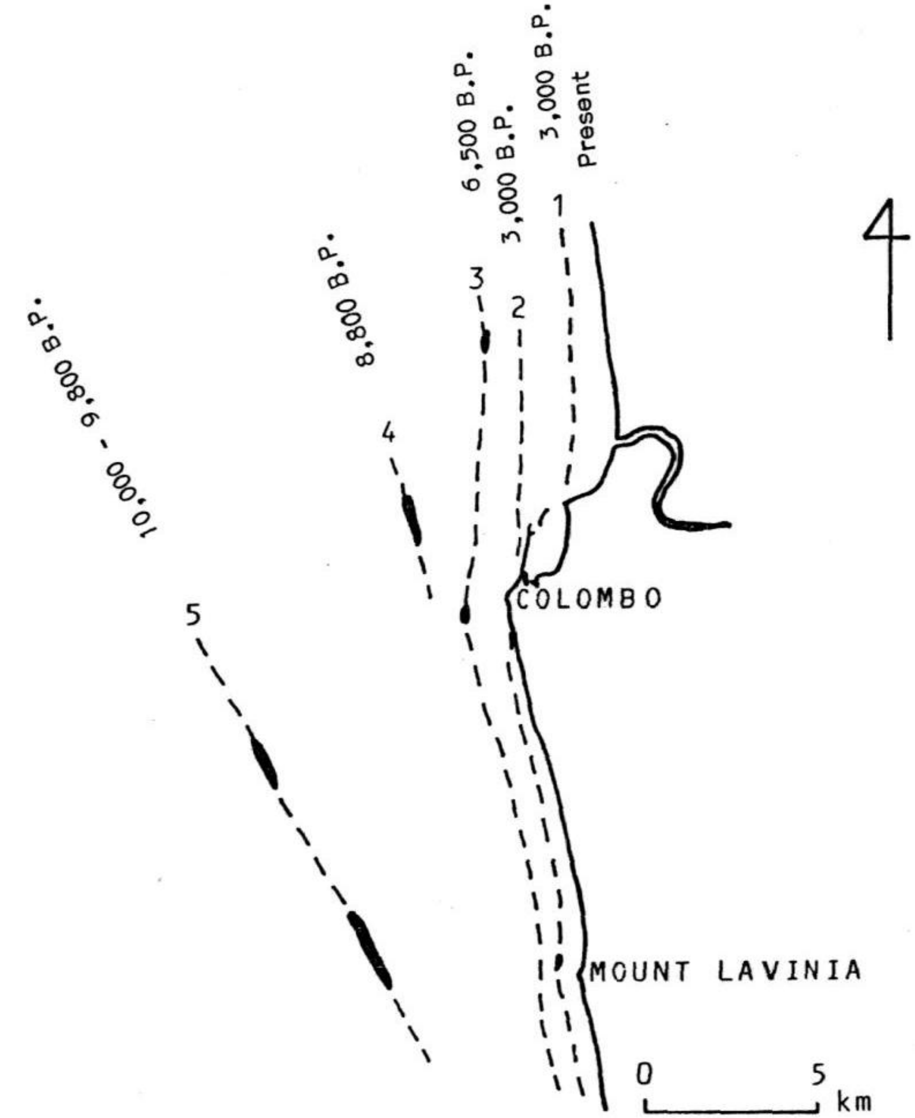


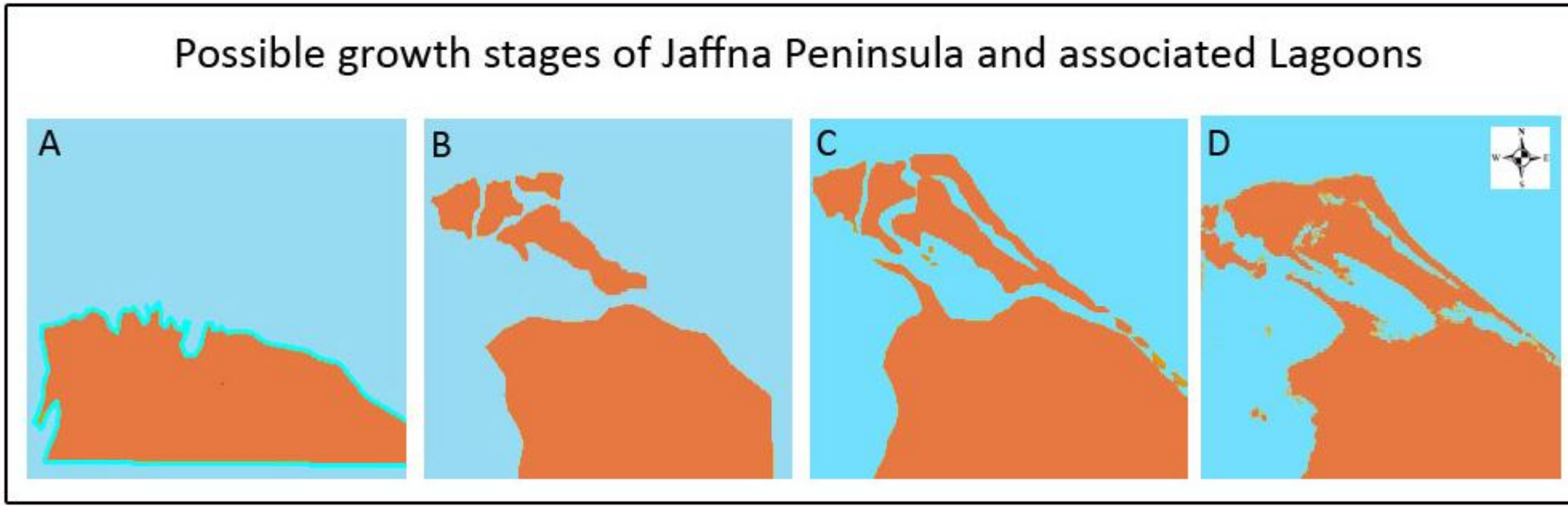
Fig. 7. Depth sequence and possible ages of beachrock on the western continental shelf in Colombo region (After Swan, 1983 and Katupotha, 1991).

Origin and Evolution of Lagoons Due to Sea Level Changes

At least five stages can be identified in relation to the lagoon origin and evolution:

Stage 1: From Late Pleistocene to Early Holocene.
The climatic, sea-level and ecological changes between the Late Pleistocene and Early Holocene Epochs in Sri Lanka followed the dry climatic conditions.

By the end of this stage, the sea level was -10m to -20m below the present level and there was no any signs relation to present lagoons in Sri Lanka.



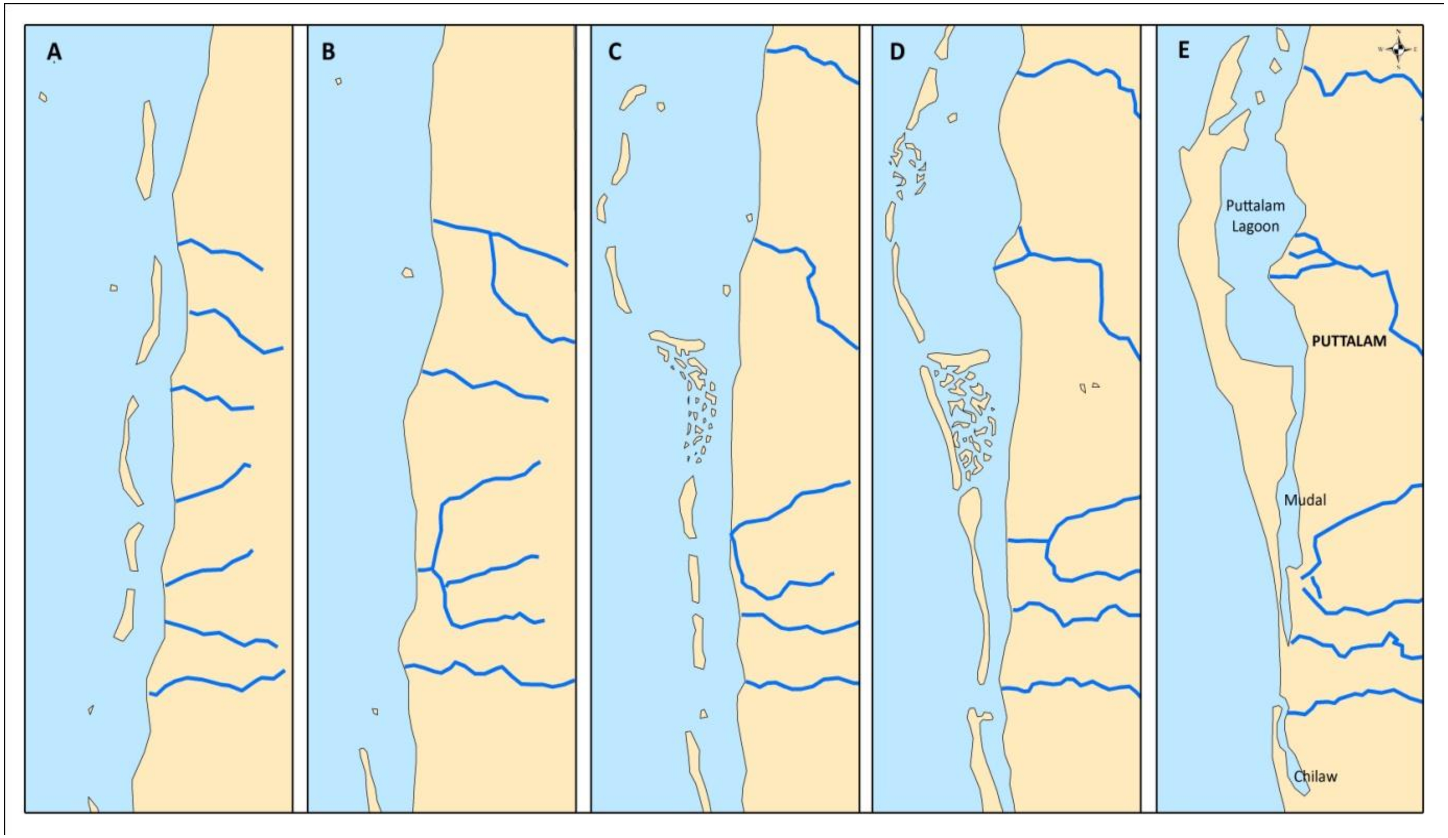
. From available geological and geomorphological evidence, it is possible to trace the evolution of Jaffna Peninsula and associated lagoons as follows:

A. Drowning of Miocene rocky islands due to the Mid Holocene sea level rise,

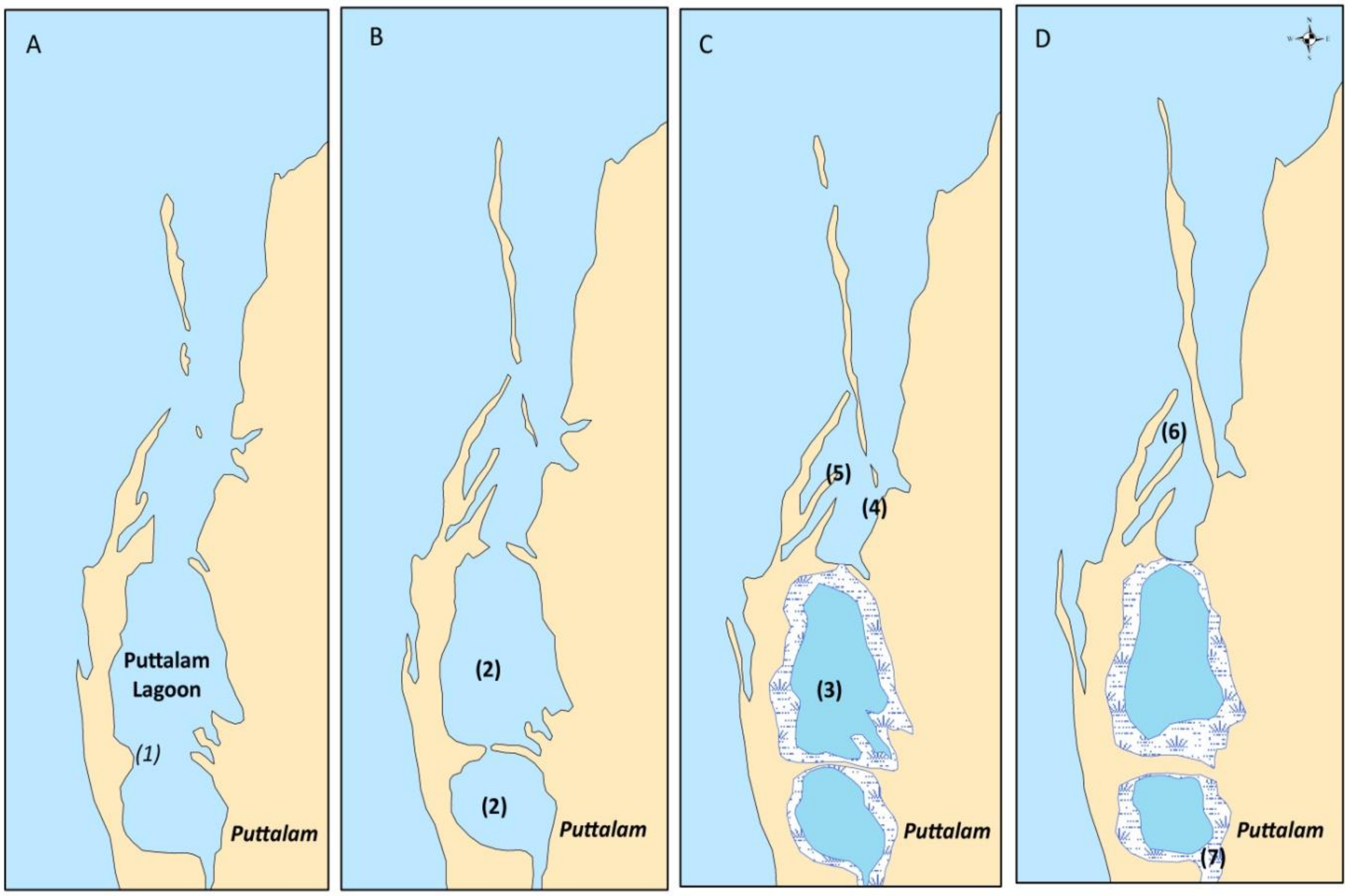
B. Due to the lowering of sea level Late Holocene time Miocene islands were emerged,

C. Attachment of these islands to the mainland by sand spits, and

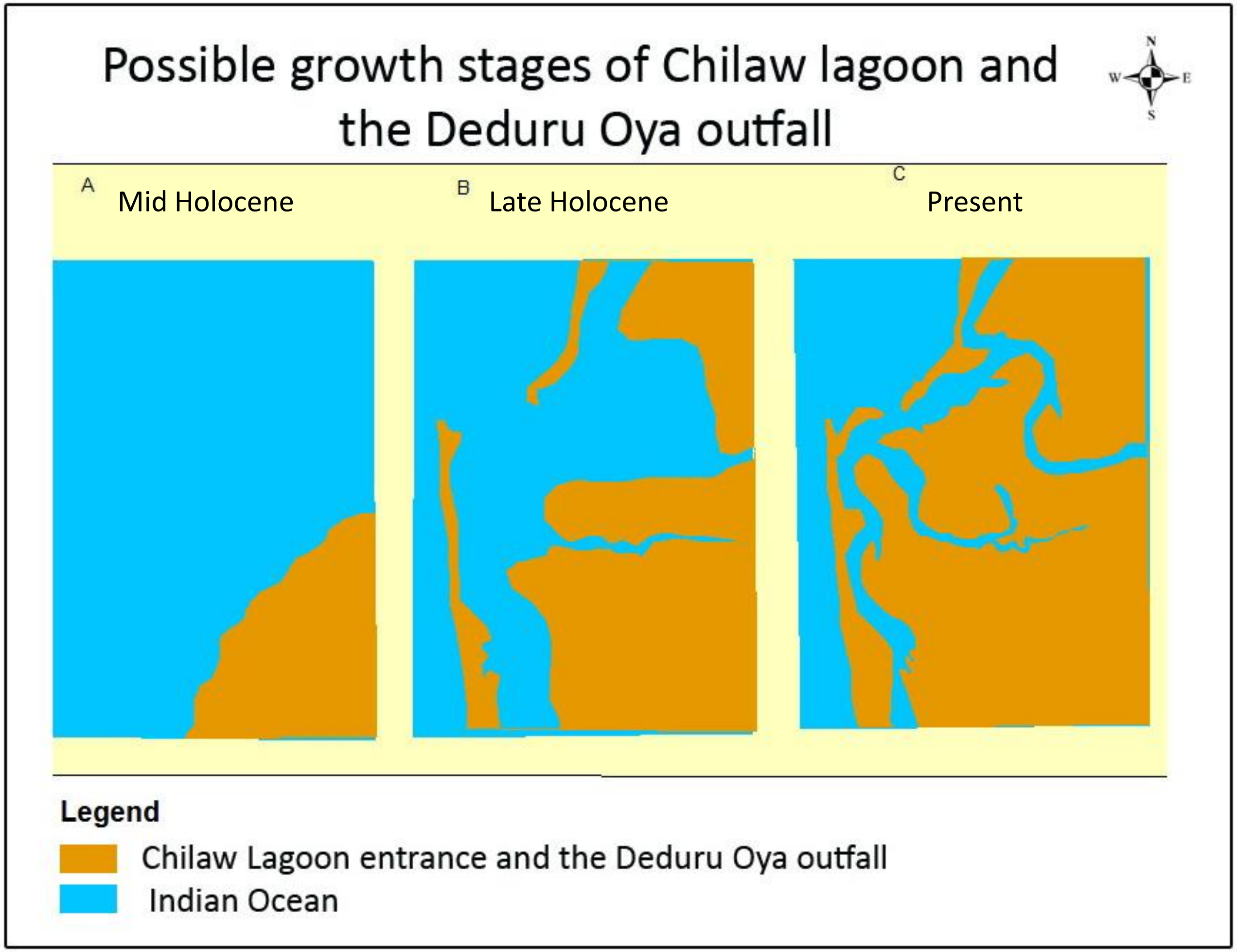
D. Present position of Jaffna Peninsula with Jaffna lagoon complex



Growth stages in the coastal region between Chilaw Lagoon and Puttalam Lagoon.



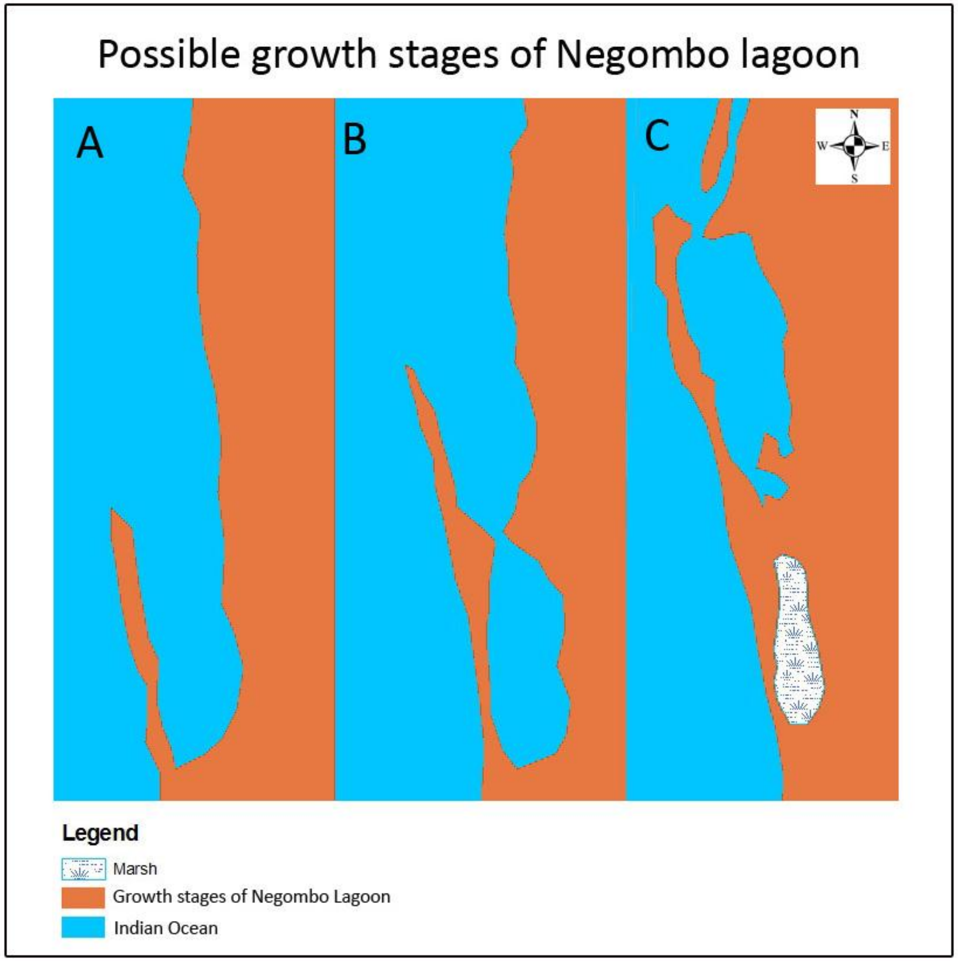
The sequence of formation of the Puttalam "lake" and Kalpitiya "lagoon"



Chilaw Lagoon and Deduru Oya outfall

:

The present coastal configuration in Chilaw area is a result of sand spit and sand bar growth, leading to formation of a lagoon. This was subsequently filled up, and Deduru Oya, presently flows through old lagoon and lake beds.



At Negombo, it is possible to recognize the following stages:

- Formation of wide beach plain with parallel ridges and runnels ? (as in) Puttalam;
- Growth of barrier spit and barrier bar;
- Formation of Negombo lagoon;
- Silting up of lagoon and reduction to its present size

There is no lagoons related to Pleistocene Epoch

Evidently, lagoons in Sri Lanka are related to Mid and Late Holocene sea level fluctuations.

Journal of Coastal Research	11	4	1042–1061	Fort Lauderdale, Florida	Fall 1995

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

KATUPOTHA, J., 1995. Evolution and geological significance of Holocene emerged shell beds on the southern coastal zone of Sri Lanka. *Journal of Coastal Research*, 11(4), 1042–1061. Fort Lauderdale (Florida), ISSN 0749-0208.

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 on 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.*

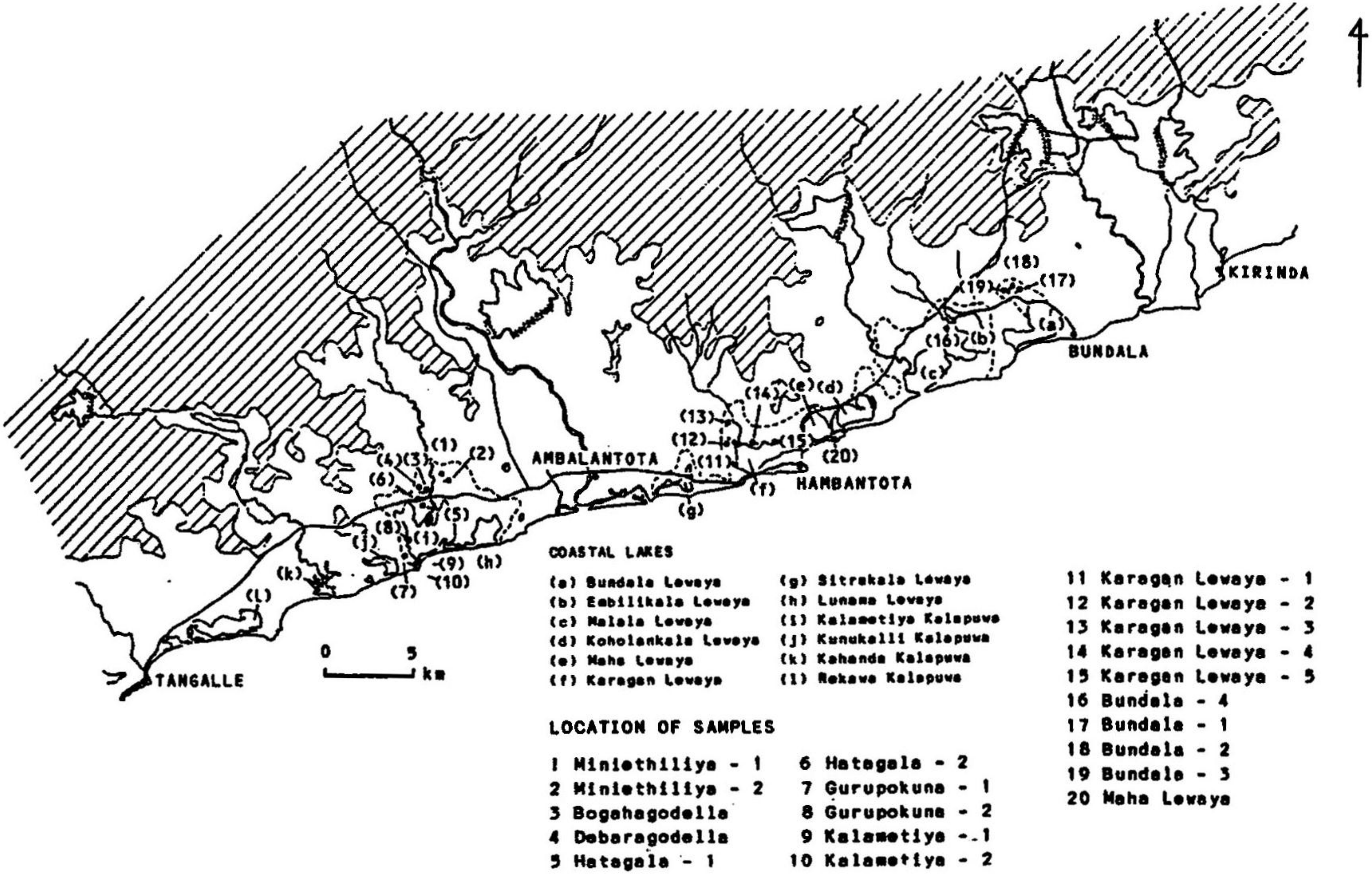
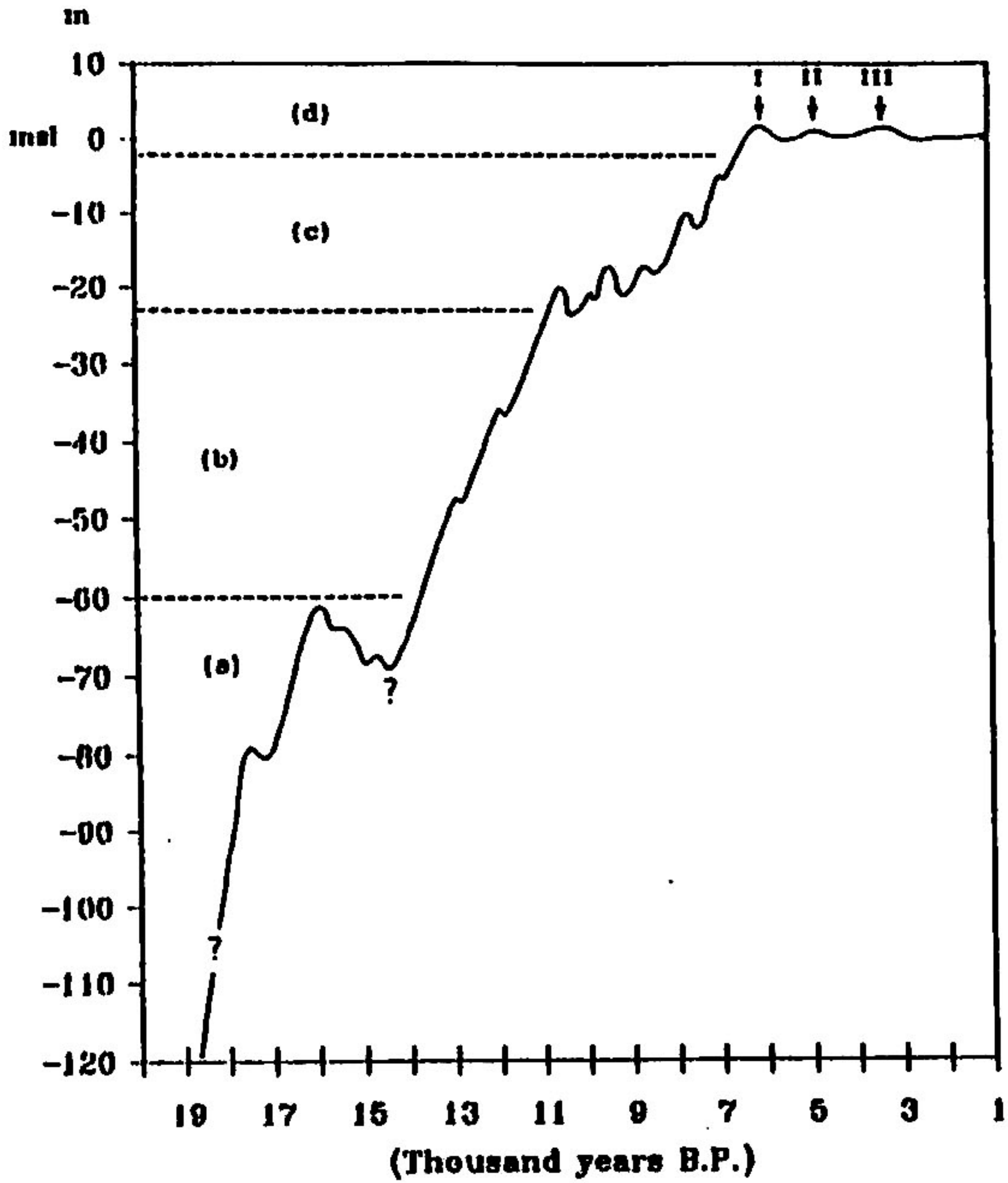
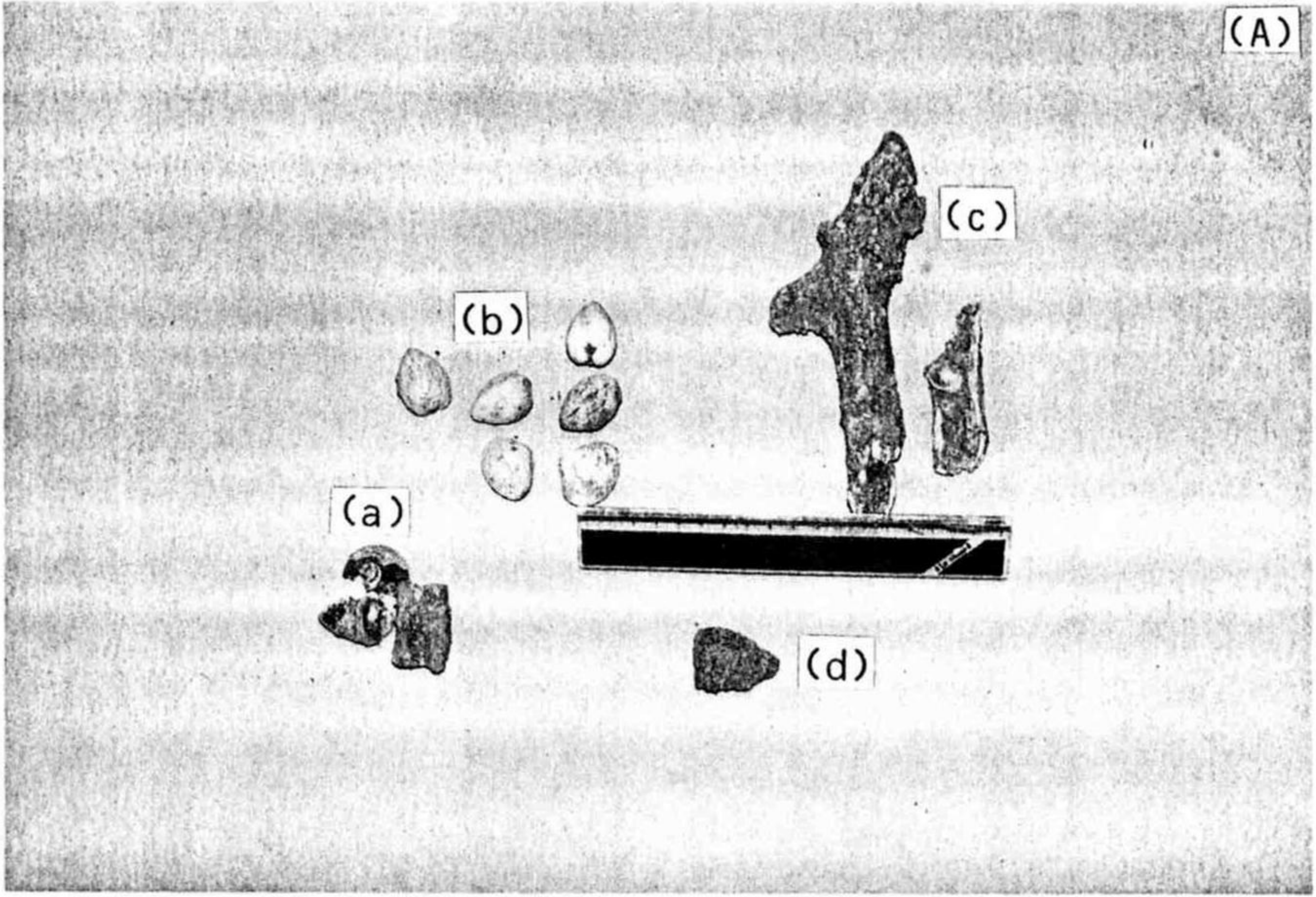


Figure 2. Extension of marine shell beds along the southern coastal zone.


m
10
msl 0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
(d)
(c)
(b)
(a)
?
?
I
II
III
19
17
15
13
11
9
7
5
3
1
(Thousand years B.P.)


(A)
(a)
(b)
(c)
(d)

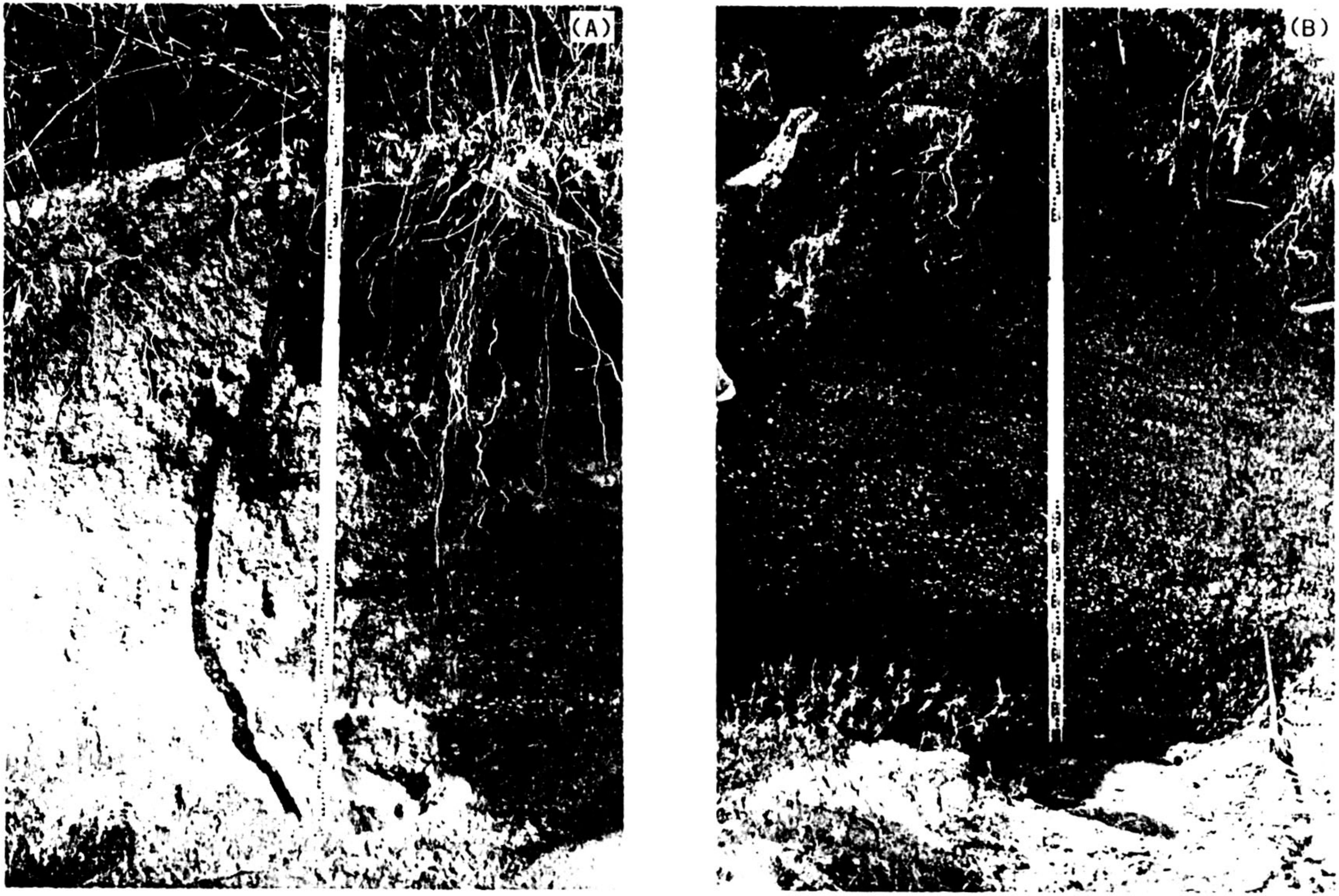
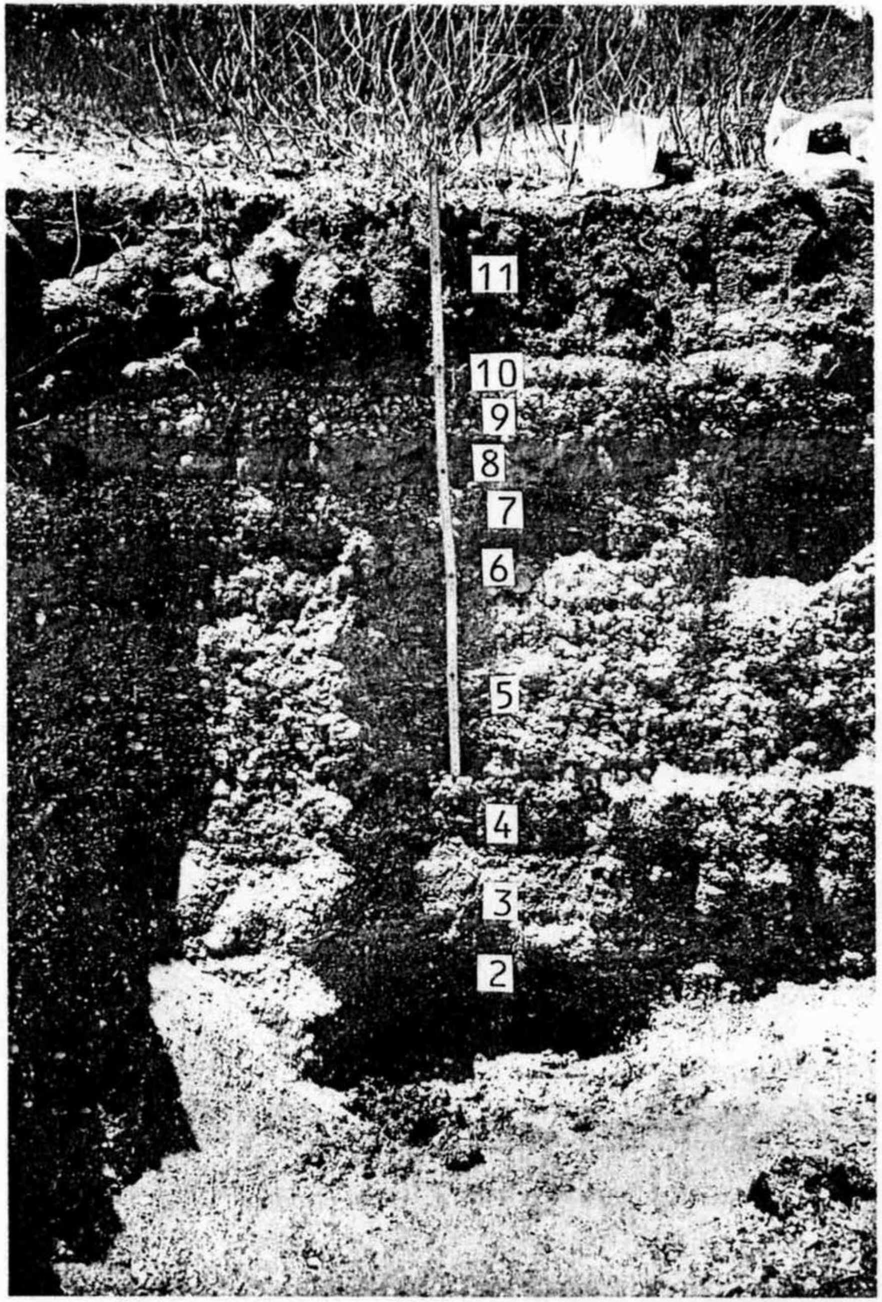


Plate 4. (A and B) Horizontal deposition patterns of the shell beds at Bataata-Gurupokuna indicate the shell valves have piled up by severe storms (Location No. 7 and 8).



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 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.

The period follows the Wisconsin glaciations (also known as the Baltic-Scandinavian ice age or the Weichsel glacial). The Holocene can be subdivided into five time intervals, or chrono-zones, based on climatic fluctuations:

Pre-boreal (10 ka – 9 ka),
Boreal (9 ka – 8 ka),
Atlantic (8 ka – 5 ka),
Sub-boreal (5 ka – 2.5 ka) and
Sub- Atlantic (2.5 ka – present)

All these chrono-zones are useful to correlate Sri Lankan events such as geology, climate, ecological and cultural developments with other countries. Furthermore, these chrono-zones have been compared with sub-divisions of the Holocene Epoch by the author (Katupotha 1988a and 1988b) as given below:

Pre-boreal and Boreal	**Early Holocene**
Atlantic	**Mid Holocene**
Sub-boreal	**Late Holocene**
Sub-Atlantic	**Late Holocene to recent**

Photo 1. Buried coral pit nearly 5m deep at Seenigama-Akurala. Photo taken in 1991.

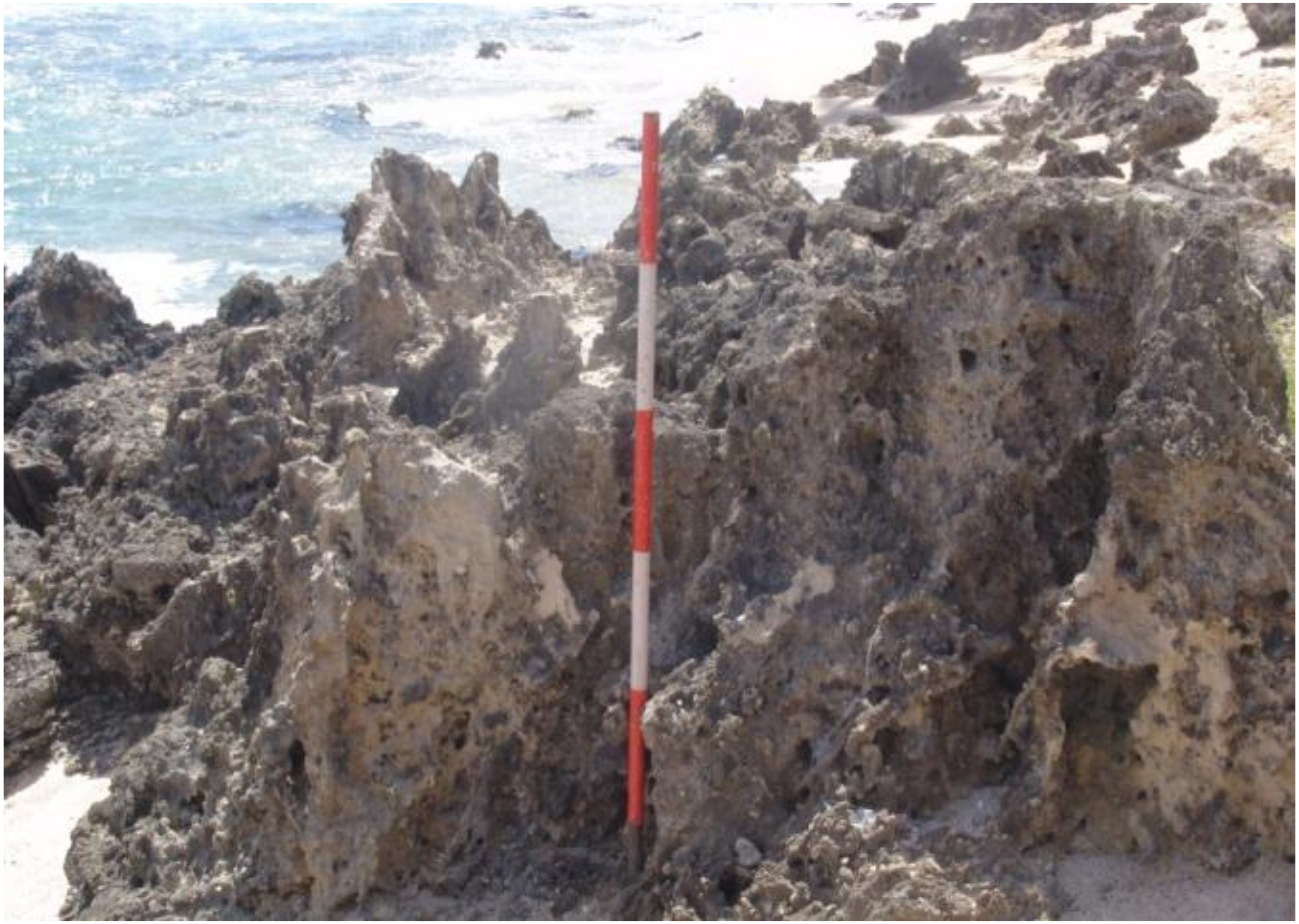


Photo 2. Emerged coral reef at Koggala. Upright corals indicate growth following the mid Holocene transgression.

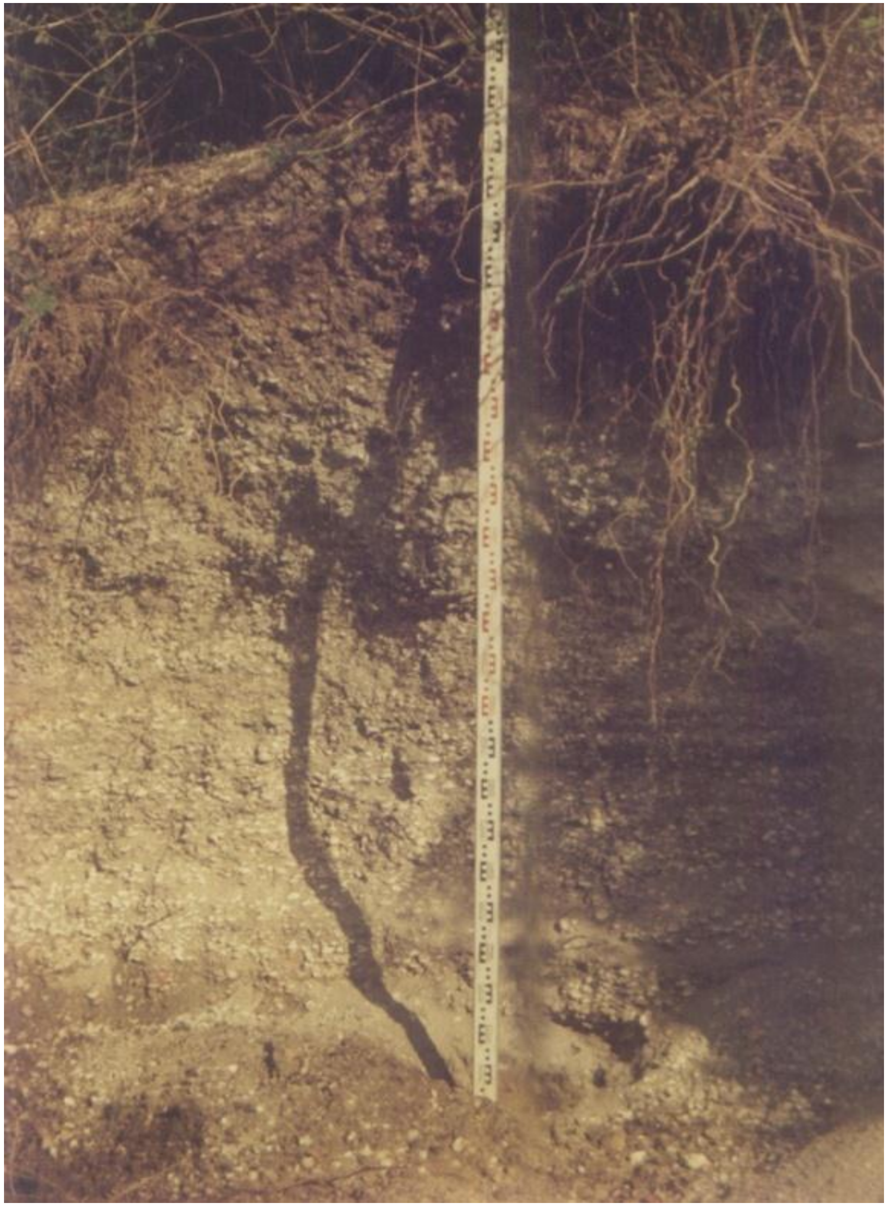


Photo 3. A thick layer of marine shells and shell debris that has piled up due to strong wave action at Bata-atha.

Photo 4. Thick layers of marine shells and shell debris that have deposited on the Kalametiya lagoon floor.

Journal of Geological Society of Sri Lanka Vol. 17 (2015), 75-86
J.W. Herath Felicitation Volume

A COMPARATIVE STUDY OF SEA LEVEL CHANGE IN MALDIVES AND SRI LANKA DURING THE HOLOCENE PERIOD

JINADASA KATUPOTHA

Department of Geography, University of Sri Jayewardenepura, Nugegoda 10250, Sri Lanka
e-mail: katupotha@sjp.ac.lk

ABSTRACT

All the morphological features that comprise the continental shelf of the Maldives Islands and Sri Lanka share a geological history attributed the Quaternary period and reveal Pleistocene and Holocene sea level changes in both countries. The island chains of Maldives and on/near shore areas of the continental shelf of Sri Lanka are composed primarily of reef-derived carbonate sediments deposited during post-glacial and interglacial periods, in relation to sea level changes. However, research work carried out in Sri Lanka on sea level change is scanty compared to Maldives for an in-depth comparative study.

This paper attempts to examine the similarity of the Holocene sea level changes in the Maldives and Sri Lanka based on the review of relevant published research papers, Radiocarbon isotopic radiometric dates and changes to past sea level curves.

Key words: Holocene high sea levels, Islands and island chains, Maldives, Sri Lanka

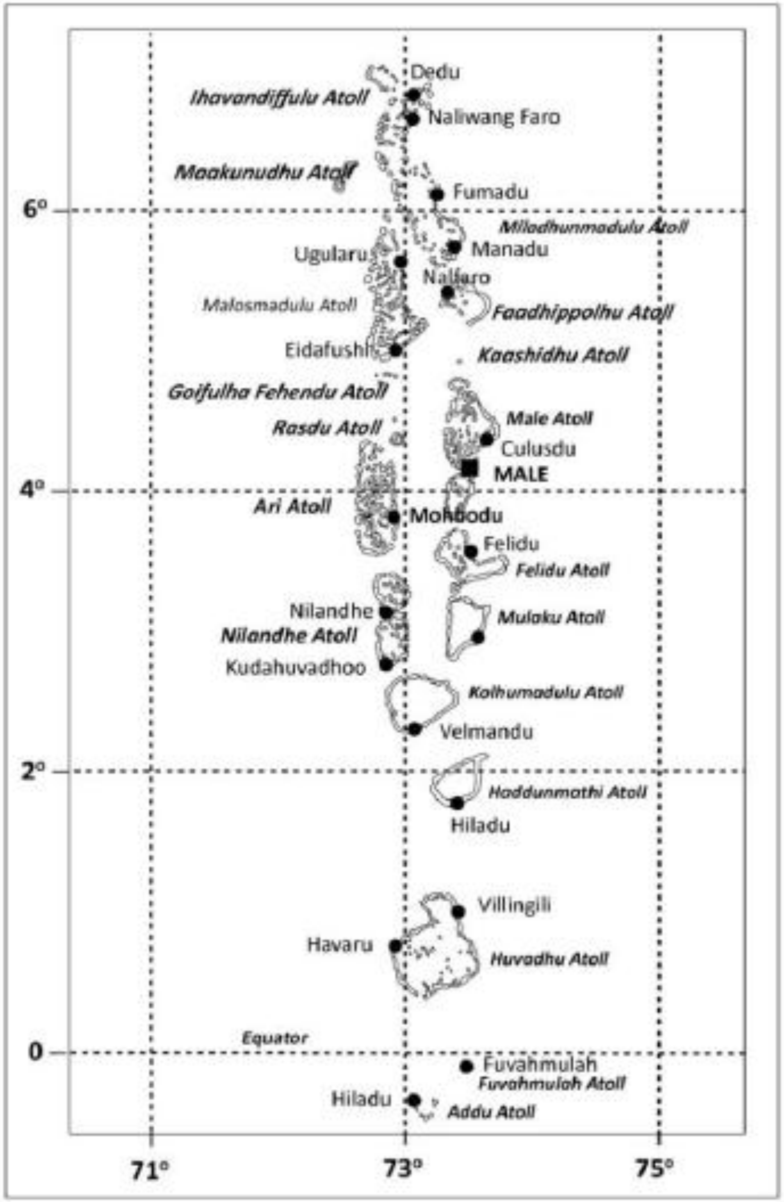


Fig. 1 Geographic distribution of the Natural Atolls of the Maldives (Source: Mörner, at el 2004: Kench at el, 2009; Woodroffe, 2008. Modified by Katupotha 2015)

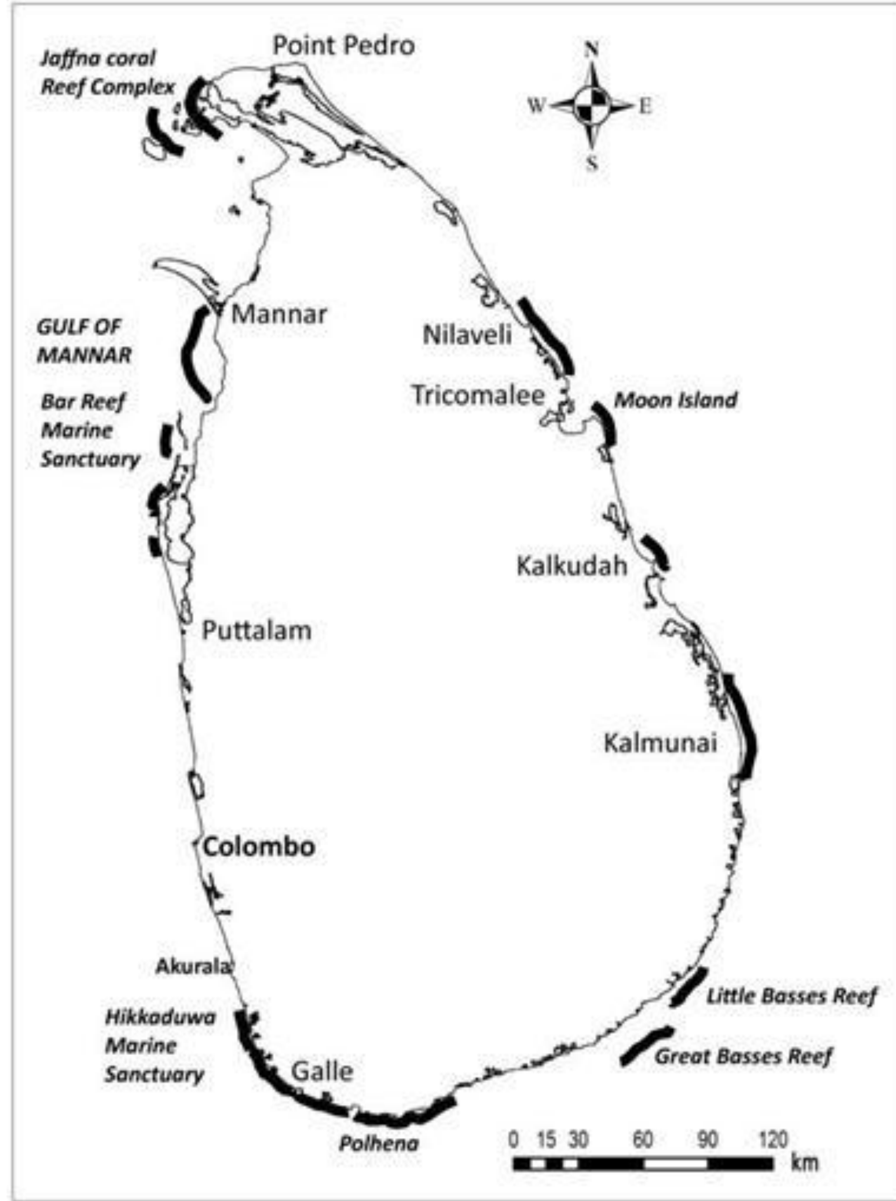
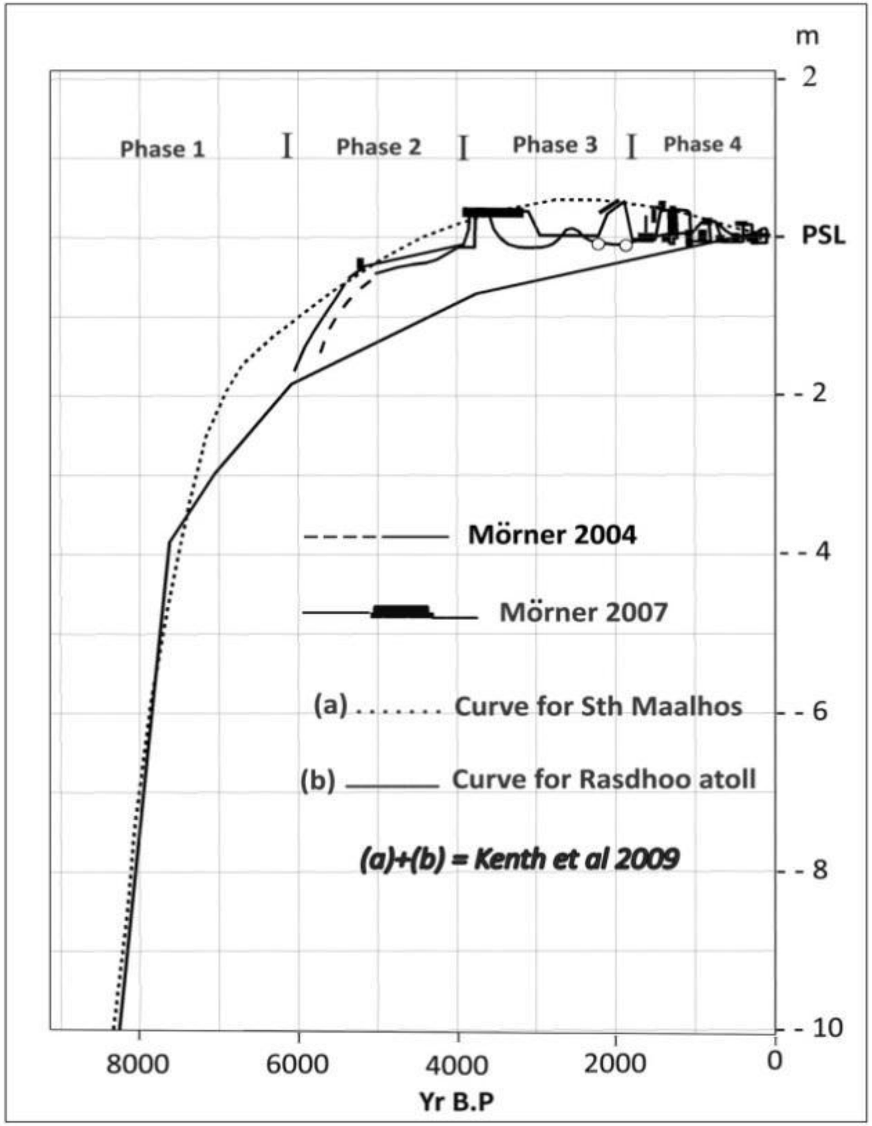


Fig. 2 Distribution of coral reefs in Sri Lanka (Source: Rajasuriya, 1994; Rajasuriya and White 1994; Redrawn by Katupotha 2015).

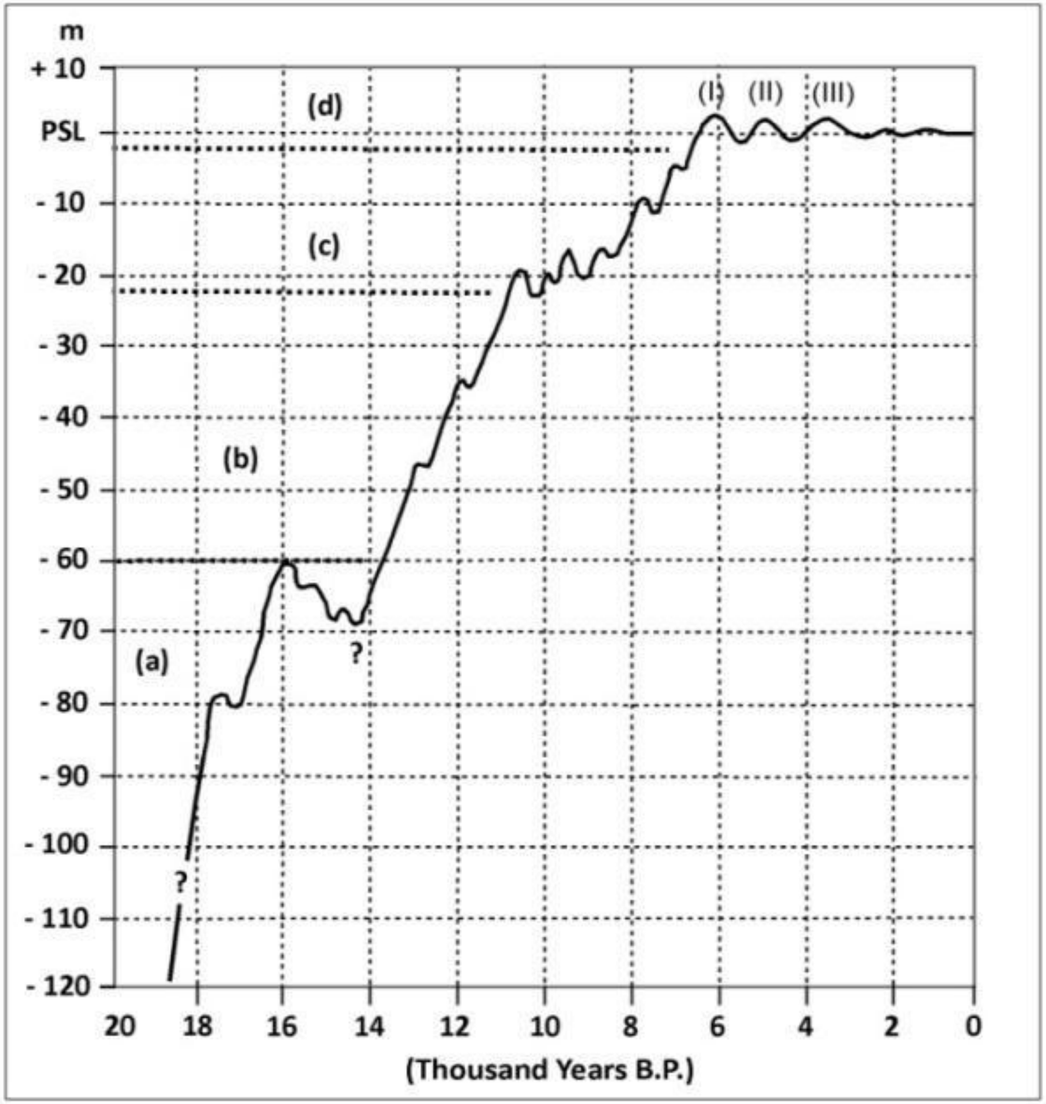


Sea level curves for the last 6000 years (Morner et al, 2004; Mörner, 2007; Kench, et al 2009, Modified and redrawn by Katupotha 2015)

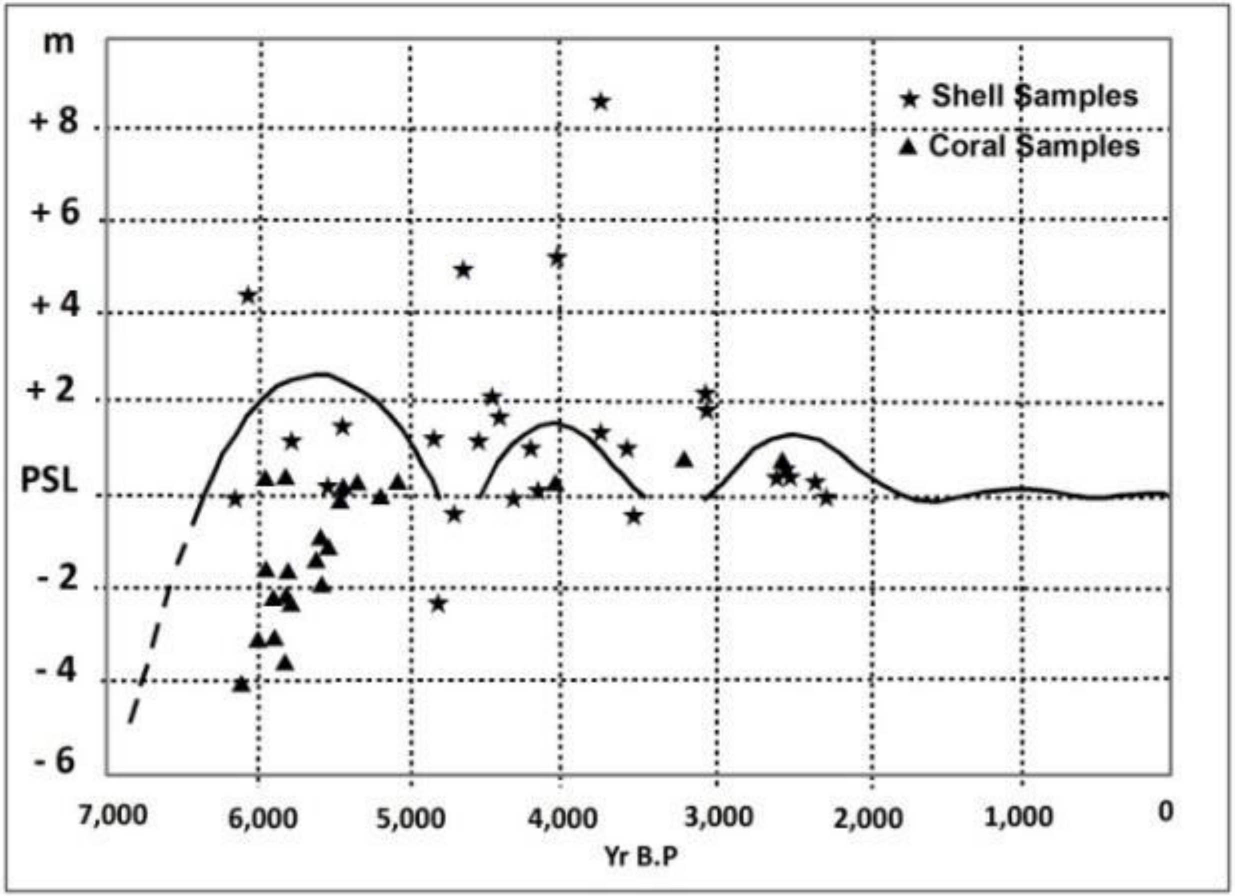
Table 1 New Radiocarbon dating of shell samples collected from Southern Coast, Sri Lanka

No.	Sampled area	Elev.	Age (yr BP)	USS No.
1	Miniethiliya 1 (HG)	+1.4 ~ +1.5	3750± 40	ST14228
2	Hatagala 5-1 (HG)	+1.1	4200± 35	ST14229
3	Hatagala 5-2 (HG)	+0.2	4175± 40	ST14230
4	Hunukotumulla 12	+4.45	6080± 60	ST14232
5	Arabokka 14 (KM)	+1.6	5460± 60	ST14233
6	Bundala 18	+8.7	3760± 45	ST14234
7	Bataata 8-2	-0.3	3530± 70	ST14231

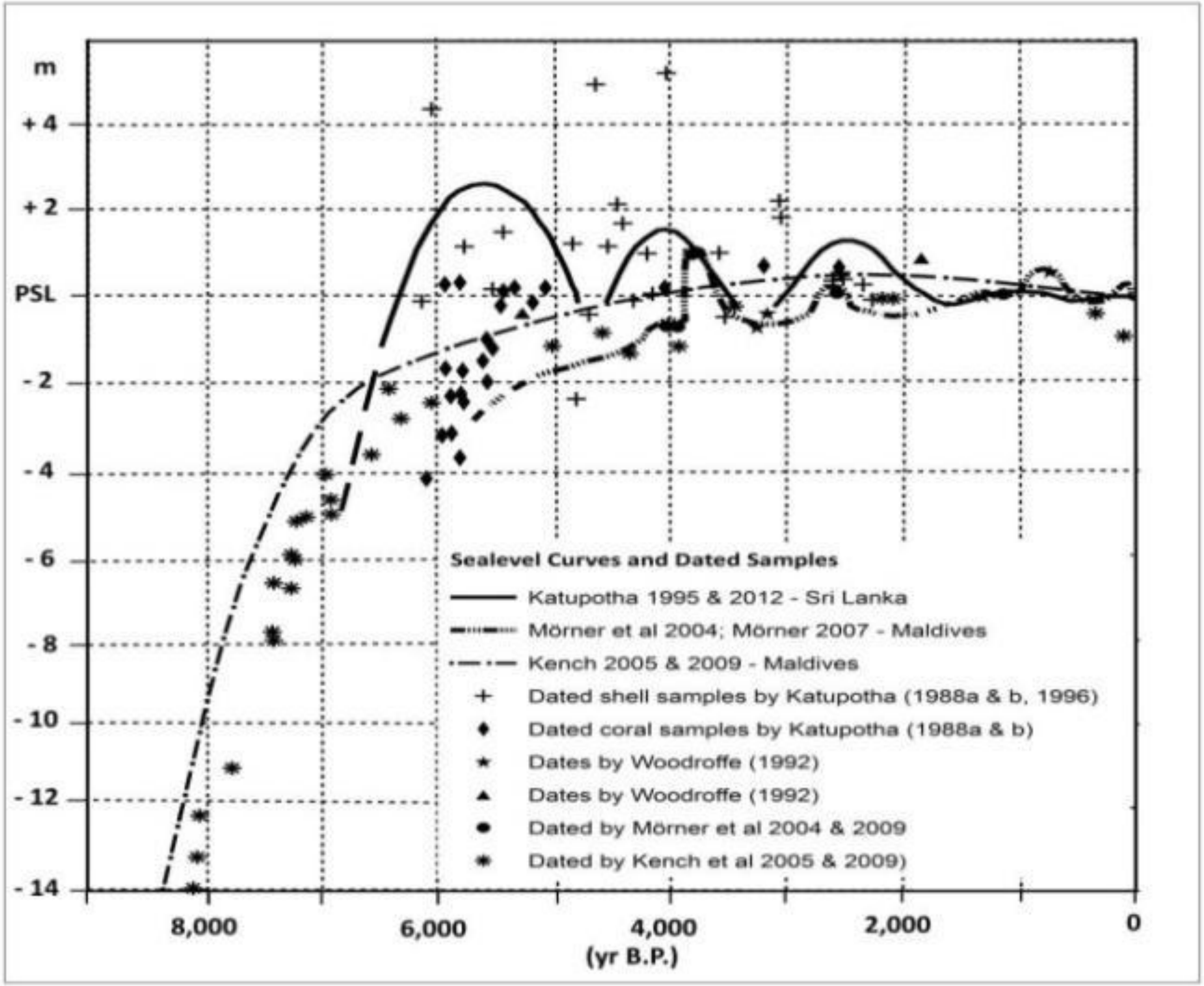
HG = Hungama, KM = Kalametiya, STI = Department of Quaternary Research, University of Stockholm, Sweden.



Sea-level oscillations in Sri Lanka since Last Glacial Maximum (Katupotha 1995; Redrawn by Katupotha (2015) using new 7 RADIOCARBON ages (Table 1)



Mid and Late Holocene high sea-level episodes in Sri Lanka, Katupotha 1988c, 1994 & 1995). The curve modified using new ages.



Holocene sea level fluctuations indicate that some similarities can be identified from the curves depicted by Katupotha (1994 & 1995), Kench (2005 &2009) and Mörner et al (2004) and Mörner 2007); Redrawn by Katupotha, 2015.

All these events evidently related to the origin, formation and evolution of coral islands, reefs and coral patches as well as shell deposits in Sri Lanka. Based on that it is possible to identify five stages in relation to sea level changes in Sri Lanka:

Stage 1: From Late Pleistocene to Early Holocene.

Sea-level and ecological changes as well as cultural phases between the Late Pleistocene and Early Holocene Epochs in Sri Lanka have been followed the dry climatic conditions.

By the end of this stage (phase), the sea level was -10m to -20m below the present level (Figure 4) and the submerged reefs, islands are related to this phase.

The levels of this stage can be clearly correlated with the Anderson's (1998) and Mörner et al, (2007) descriptions.

(b) Stage 2: Mid Holocene Period (first episode of high sea-level; 6,240-5,130 years BP).

Radiocabon dates (C^{14}) of emerged coral samples from the west, south and east coasts by Katupotha (1988a, 1988b), Katupotha and Wijayananda (1989) indicate that the mid-Holocene sea level was at least 3-5 high that of the present level in Sri Lanka.

This sea level variation during this period can be correlated with Maldives, India and other islands in the Indian Ocean (Katupotha, 1990).

Although, the Maldives high sea levels were not exceed the Sri Lanka's high sea level, these happened during the same period (Mörner et al, 2004, 2007; Kench et al, 2009).

(c) Stage 3: First Phase of the Late Holocene (4,390 - 3,930 years BP, second episode of high sea-level).

Between the Stage 2 and Stage 3, the sea-level around 4,700 years BP was slight above the present MSL.

This episode of high sea level adapts with the contemporaneous Holocene high sea levels of Maldives.

(d) Stage 4: Second Phase of the Late-Holocene (3,280 - 2,270 years BP, third episode of high sea-level).

Between Stages 3 and 4, the sea-level around 3,600 years BP was also at or below the present MSL.

It is suggested that the beach rock, slightly above supra-tidal level zone along the coast formed during this stage.

This level also largely coincides with the mentioned sea level curves.

(e) Stage 5: Development of 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 around AD 1850.

Fairbridge's (1961) studies also indicate the rise of sea-level and glacial retreat since 100 years BP. Many archaeological sites, monuments, Forts, monasteries and other physical features along the coast of Sri Lanka elegantly coincide with the Mörner's (2004, 2007) and Kenth et al (2005, 2007) findings.

Recent sea level changes

	Total Inundated Area (ha)			
District	25 Year	50 Year	75 Year	100 Year
Colombo	959	1,133	1,327	1,534
Gampaha	3,638	4,154	4,631	5,073
Puttalam	11,334	12,583	13,716	14,809
Mannar	8,024	8,262	8,518	8,758
Jaffna	10,321	11,164	12,014	12,891
Mullaittivu	912	1,004	1,092	11,80
Trincomalee	2,315	2,529	2,791	3033
Batticaloa	2,325	2,443	2,568	2,702
Ampara	1,880	2,175	2,479	2,762
Hambantota	4,265	5,553	6,516	7,322
Matara	1,277	1,634	1,994	2,401
Galle	5,622	6,462	7,249	8,014
Kalutara	1,956	2,370	2,790	3,203

Table 7.3 Total inundated area in each district including water bodies

	Additional Inundated Area (ha)			
District	25 Year	50 Year	75 Year	100 Year
Colombo	201	375	569	776
Gampaha	459	976	1,452	1,894
Puttalam	1,113	2,362	3,494	4,587
Mannar	248	486	741	981
Jaffna	864	1,706	2,557	3,434
Mullaittivu	88	180	268	355
Trincomalee	252	467	729	971
Batticaloa	130	247	372	507
Ampara	293	588	892	1,175
Hambantota	885	2,173	3,136	3,942
Matara	384	741	1,101	1,508
Galle	776	1,617	2,403	3,169
Kalutara	417	830	1,251	1,664

Table 7.4 Inundated area in each district excluding water bodies

Sea Level Rise
Hazard Profiles of Sri Lanka

Fig 7.5 *Headland that may go underwater due to sea level rise*

Fig 7.6 *Headland that may not go underwater due to sea level rise*

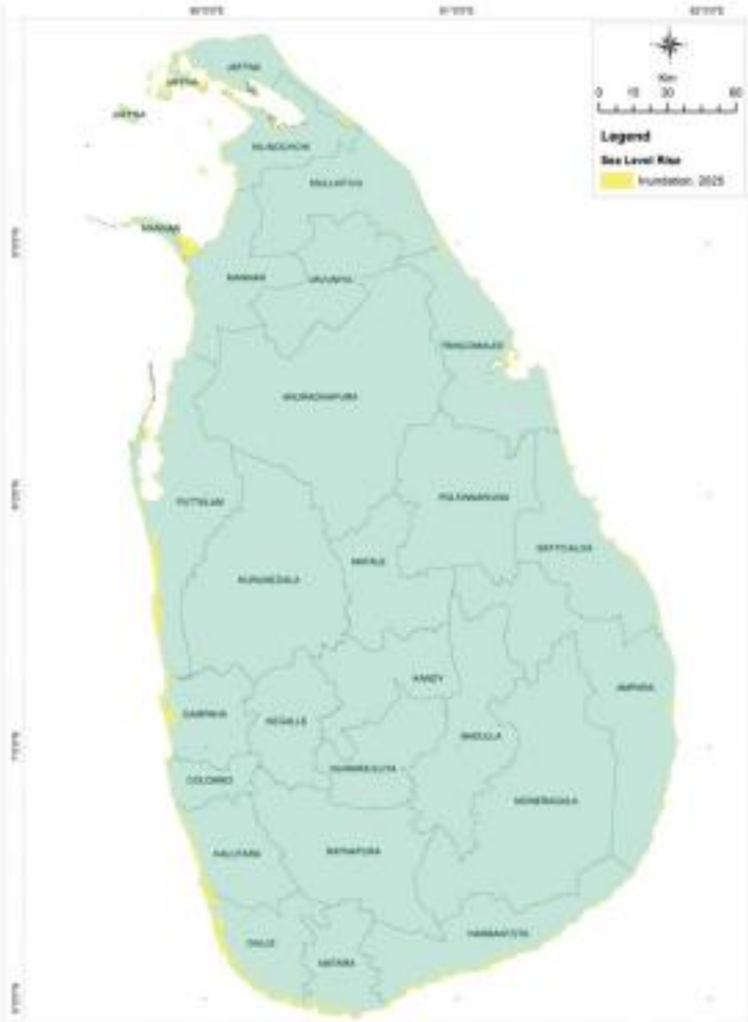


Fig 7.7: Predicted sea level rise in 2025 in Sri Lanka

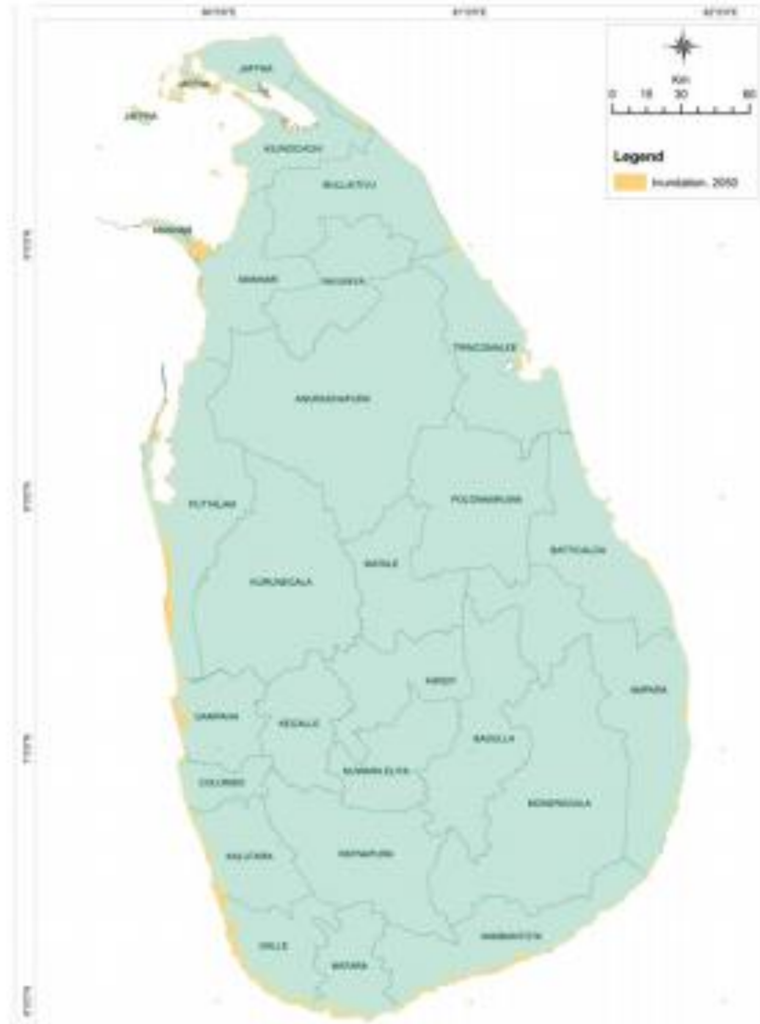


Fig 7.8: Predicted sea level rise in 2050 in Sri Lanka

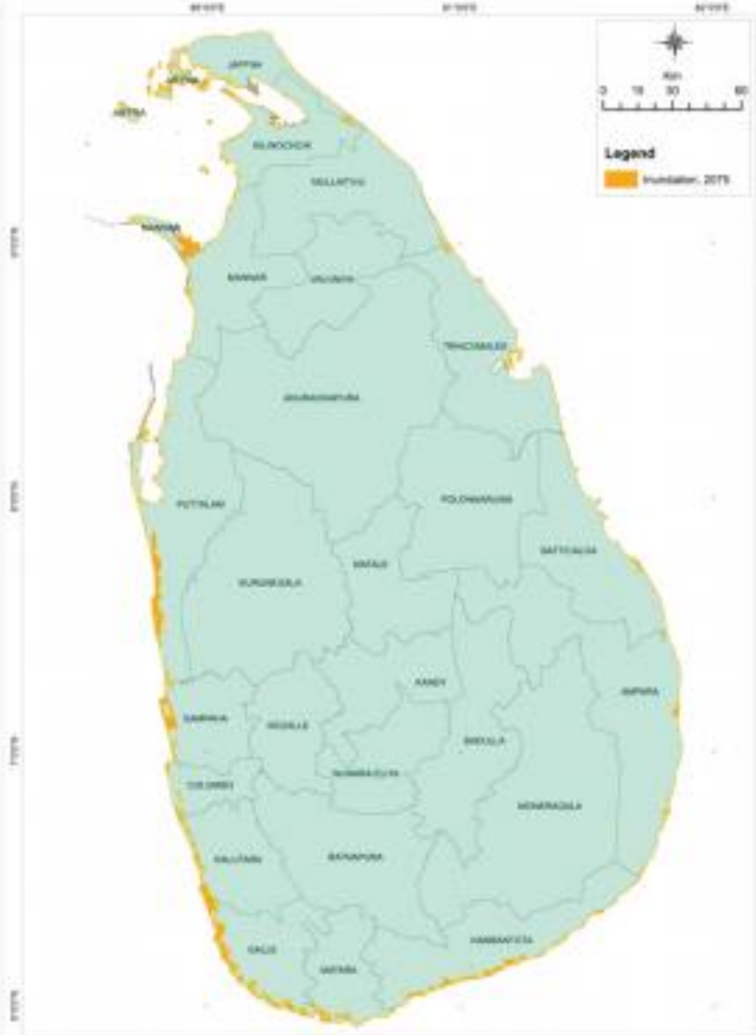


Fig 7.9: Predicted sea level rise in 2075 in Sri Lanka

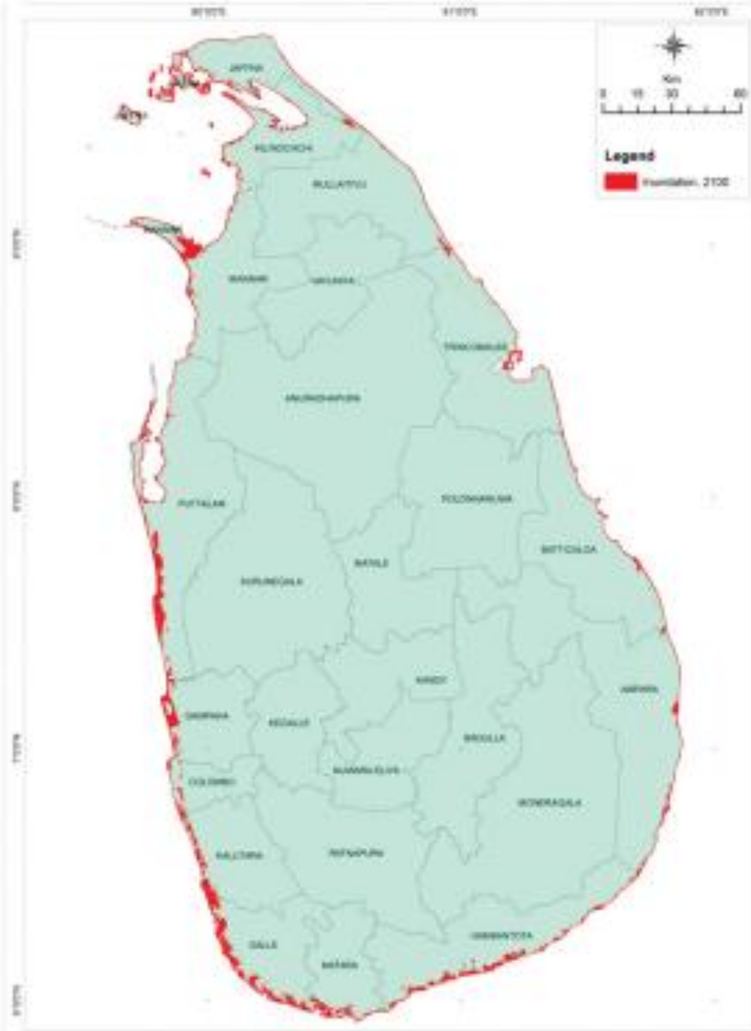
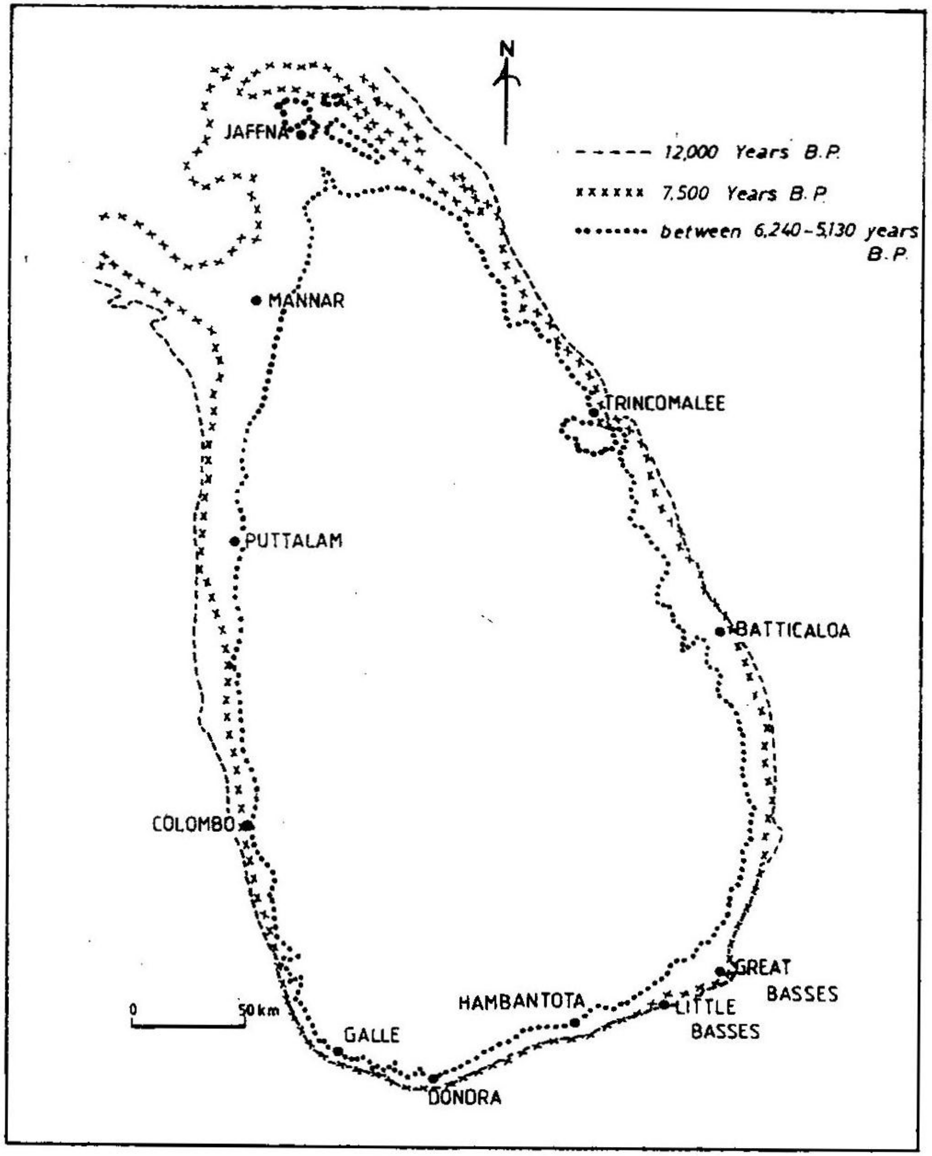


Fig 7.10: Predicted sea level rise in 2100 in Sri Lanka



Possible coastlines of Sri Lanka (i) 12,000 yr B.P; (ii) around 7,500 yr B.P. and (iii) between 6,250 and 5,130 yr B.P. By 2,100 the sea level will rise 1.0m 1.2m or more from the present level.

Acknowledgements:

The author used additional seven ^{14}C dates (Nos. 50-56 in Table 1, which were published in Katupotha (1988a & 1988b). I wish to express my grateful thanks to Professor Jan Risberg of the Department of Quaternary Research, Stockholm University, who helped me personally to obtained radiocarbon age measurements through the University during my visit to the Department of Physical Geography, Stockholm University in 1996.

THANK YOU