

Evolution of the Kalu Ganga - Bolgoda Ganga Flood Plain System, Sri Lanka

P. Wickramagamage

Department of Geography, University of Peradeniya, Peradeniya, Sri Lanka.
(*email: wickramagge@yahoo.com*)

ABSTRACT

The Bolgoda Ganga catchment shows all the signs of a relict hydrogeomorphological feature. It has many hydrogeomorphological anomalies, such as disproportionately large estuary and floodplain, presence of a valley extending South to North, presence of an off-shore canyon off the mouth of the Bolgoda Ganga. Furthermore, the Bolgoda Ganga and Kalu Ganga catchments were inter-connected even before the construction of the Kepu Ela. This study attempts to elucidate the evolution of this drainage system and the geomorphology of the area.

The geomorphology of the Southwestern coastal plain of Sri Lanka has evolved during a period of rapidly occurring environmental changes, such as warming of the climate since the last glacial maximum and fluctuation of sea levels during the Holocene. The drainage system has developed in response to these changes. Examination of the geomorphology and stratigraphy of the Bolgoda Ganga flood plain indicates that the most probable palaeo-river that flowed into the Bolgoda estuary was the Kalu Ganga. The strongest evidence in this regard is the presence of gem gravel similar to those of the Ratnapura area (Kalu Ganga Basin) in the Bolgoda sedimentary terraces and the floodplain. The changing characteristics of fluvial sediment in the floodplain indicate that the climate also changed during the recent past. This change is from a wetter climatic phase, possibly represented by the Ratnapura pluvial phase, up to the present climate. It is responsible for the upward fining sequence of fluvial sediment in the upper terraces and changes in the lower course of the Kalu Ganga.

INTRODUCTION

The evolution of the Southwestern coastal plain of Sri Lanka has taken place against a background of a rapidly rising sea levels during much of the post-glacial period since the last glacial maximum around 18,000 years BP. By then the sea level was about 100 m below that of the present time (Dyre, 1997, p.1) exposing much of the continental shelf around Sri Lanka. The worldwide sea level rose during the last 20,000 years rapidly with the melting of polar ice sheets as the climate began to warm inundating the lower parts of the coastal plain. However, the sea level change during the last 20,000 years was not uniformly up-

ward. Several late Holocene high sea level stands (up to 3.7m) have been reported from many parts of the world at 5700, 4900, 3700, 2400, 2200, and 1000 BP (Fairbridge, 1961). Even though some doubt that there ever were higher sea levels during the late Holocene (Kidson, 1986), evidence to the contrary has been reported from tectonically stable lands such as Sri Lanka (Katupotha, 1995; Weerakody, 1988, 1992). Katupotha (1995) suggests that there were at least three episodes of higher sea level stands in Sri Lanka during the late Holocene around 5500 BP, 4000 BP and 2500 BP. Fairbridge (1961) claims that sea lev-

el was about 3-5m above the present level between 6000-4600 BP. The Sri Lankan evidence also shows higher sea levels up to about 5m above the present level (Weerakkody, 1988).

The rising sea level would have brought about changes such as the drowning of the lower courses of rivers, changing the base level of erosion, reducing the competence of the rivers to carry sediment, etc. The fluctuation in the sea level would have led to alternation between freshwater and brackish water conditions in the basins of sedimentation in the low-lying areas of the coastal plain. It has also been noted that the floodplains of many rivers in Sri Lanka are covered with thick layers of alluvium, extending to a depth well below the present sea level (Cooray, 1984; Erb, 1984). A growing body of evidence suggests that the glacial periods are associated with aridity and interglacial periods with humid conditions (Premathilake and Nilsson, 2001). These changes in the climate and associated sea level fluctuations would also have had a profound effect on the drainage pattern of the coastal plain of the island. The present drainage pattern of the Southwestern coastal plain reflects hydrological feedbacks to these changing environmental conditions. This is remarkably evident from the Bolgoda and Kalu Ganga Basins. The Bolgoda basin sandwiched between the Kalu Ganga Basin to the South and the Kelani Basin to the North is somewhat of an anomaly due to the following:

The Bolgoda River and the estuary (two lakes, the Bolgoda Ganga and Panadura Ganga), are disproportionately large compared to the total area of the Bolgoda basin and its present discharge. It is more like the lower reach of a large river. The combined area of the lakes and channels is about 18 km² in a basin of only 395 km². The two lakes situated in the lower basin appear to be remnants of a large estuary. The marshes around them are the silted up parts of this palaeoestuary. The present drainage pattern is a total mismatch for such a large estuary.

The second anomaly is that the main channel that flows from South to North connecting the two lakes is connected on the South by a silted up broad valley. The present channel of the Kalu Ganga is separated from this valley only by a slightly elevated land.

There is a man-made canal called Kepu Ele connecting the Kalu Ganga Basin with the Bolgoda Ganga.

Another important anomaly associated with the Bolgoda Ganga is the existence of an offshore canyon opposite the outfall of the Panadure Ganga. Such canyons exist off the mouths of large rivers like Niger. They are believed to be products of subaerial erosion by a powerful river or erosion by turbidity currents associated with a large river flowing into the sea (Swan, 1983). The continental shelf of Sri Lanka has ample evidence to show that the stream valleys continue into the continental shelf of the West coast (Deraniyagala, 1958). But at present, Bolgoda Ganga does not have a sufficiently high discharge capable of producing such a large canyon.

The Kalu Ganga in the South is separated from the Bolgoda basin only by a low ridge which has openings in many places. When the water level of the Kalu Ganga is high, water could have entered the Bolgoda Ganga through these natural openings even before the construction of the Kepu Ele.

All these anomalous characteristics indicate the possibility that the Bolgoda basin was a part of a much larger ancient river system. The potential candidate for this palaeo-river system is the Kalu Ganga which may have carried more water during a past pluvial climatic regime (possibly during the Rathnapura Phase described by Deraniyagala, 1958). The objective of this paper is to evaluate the available evidence to trace the palaeo-hydrogeomorphology of this region.

The Study Area

The area covered by this study includes the floodplains of the Kalu Ganga and the Bolgoda Ganga, which are two adjacent river basins and an inter-basin area situated on the southwestern coastal belt of Sri Lanka. The two river basins are inter-connected naturally through gaps in the ridge separating them and also by a canal constructed by the Dutch for navigational purposes through a pre-existing gap of the ridge. During floods, waters of the Kalu Ganga enter the Bolgoda Ganga catchment through these openings.

The Kalu Ganga, which flows in a North-westerly direction up to the Kepu Ele, turns Southwest making a sharp bend and flows into the sea at Kalutara, about 48 km South of

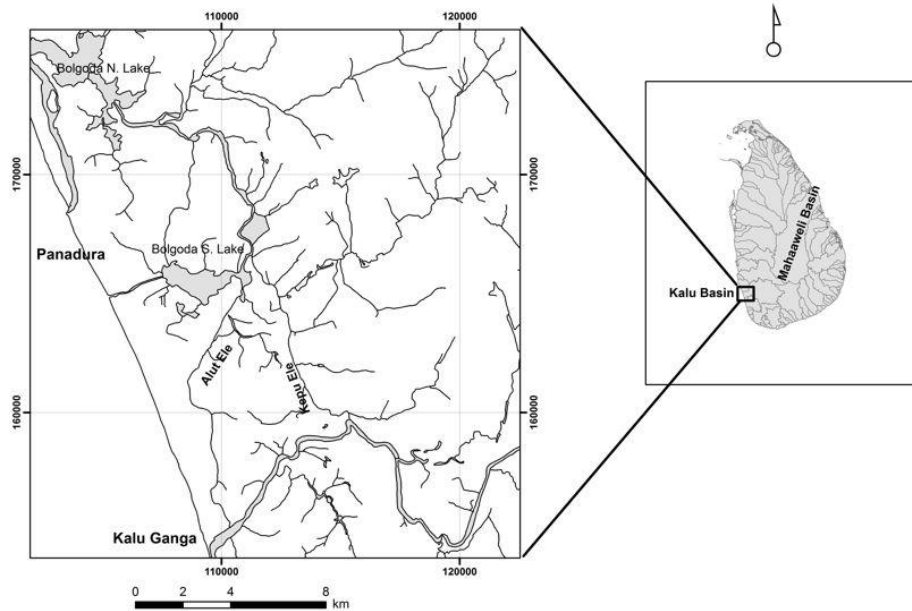


Figure 1: Kalu Ganga and Bolgoda Ganga Flood Plain Area

Colombo (Fig. 1). The position of this outfall varies annually and in some years even seasonally over a distance of several kilometers along the coastline (Swan, 1983). This movement is a direct result of the gradual growth of a spit blocking the river mouth during the low discharge in the dry season. Due to low tidal range, river mouths in the island have a tendency to be constricted or completely blocked by the growth of sand bars across the mouth obstructing the passage of water. The river mouth sand bars are found on both banks indicating the frequent reversals of the direction of the long-shore drift. The long-shore drift also changes seasonally, where the Northerly drift is more prominent during the Southwest monsoon season and Southerly drift during the rest of the year. The Southward development of the right bank sand bar is associated with the Southerly drift and the Northward development of the left bank sand bar with the Northerly drift. When the discharge is high, the sand bar is breached either naturally or artificially, to let the floodwater enter the sea fast in order to relieve pressure on the low-lying areas.

Although the size of the Kalu Ganga basin is 2,803 km², which is about a quarter of the size of the Mahaweli Basin (10,448 km²), its annual discharge is almost at the same level or slightly higher than that of the latter (Swan, 1983). The annual discharge which is about 3 MCM per square kilometer per year is the

highest in the country. This is because the upper catchment of the Kalu Ganga is situated in the highest rainfall region of the country. The headwaters of the Kalu Ganga originate at an elevation of about 2000 m and flow along narrow strike valleys occasionally cutting through strike ridges forming a typical rectangular drainage pattern (Fig. 2).

The Bolgoda Ganga by contrast has a very low annual discharge which is mostly coming from the two small tributaries, the Panape Ele and Maha Oya. They directly discharge into the North and South Bolgoda Lakes respectively. These are small streams of local origin. The outer edge of the continental shelf off the Bolgoda Ganga outfall is marked by a canyon.

DATA AND METHODOLOGY

Two types of data are used in this study. They are primary data collected by fieldwork and secondary data available in the form of maps, unpublished reports, etc. Fieldwork was carried out in the Bolgoda and Lower Kalu Ganga floodplains between the Bolgoda South Lake and the Kalu Ganga course. Gem mines provided a fine opportunity to examine the stratigraphy of the flood Plain sediments and also their characteristics. Four sediment samples were collected from a gem mine at Pelkola for textural analysis. Additional samples were collected from a dug-well at Maha Waskaduwa to the East of the Galle Road.

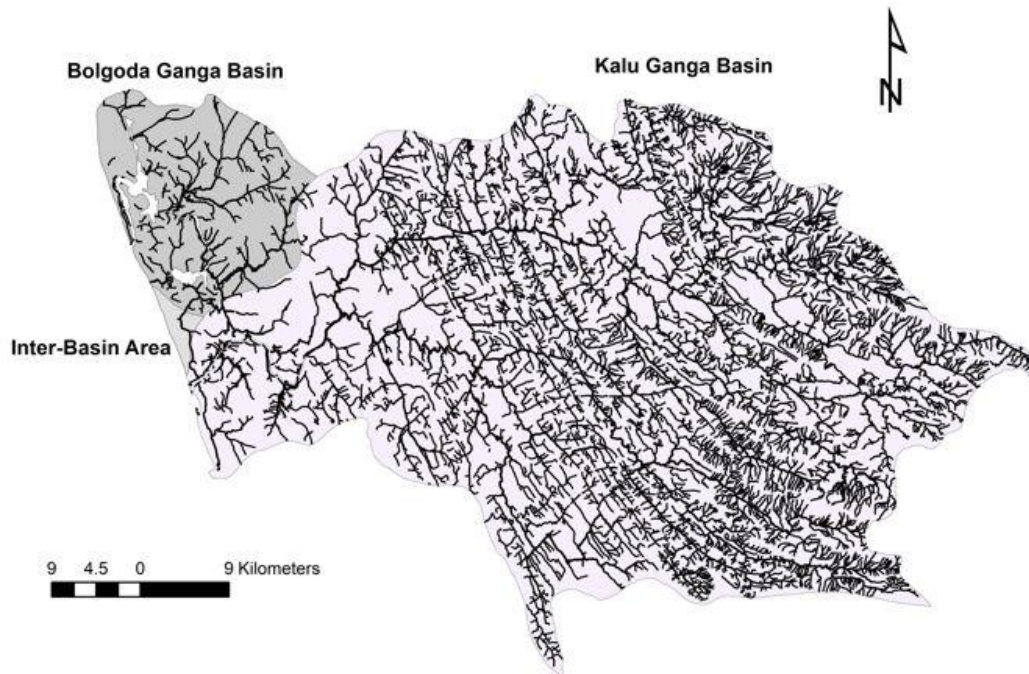


Figure 2: Bolgoda and Kalu Ganga Floodplains

Mapping of the gem mines was done using a GPS receiver (Trimble Geoexplorer II). The stratigraphic information was also gathered from the working mines. Topography of the area was constructed with the help of 1:10,000 topographic maps. Textural analysis of sand samples collected was done by means of sieving using a sieve shaker (Fritsch).

The bottom elevation of the river channel of the lower Kalu Ganga was obtained from the unpublished records of the Irrigation Department. The data were used to produce cross-sectional profiles as well as the long profile of the river based on the elevation of the deepest point.

RESULTS AND DISCUSSION

Geomorphology of the SW Coastal Plain

The coastal plain in the Southwest Sri Lanka is broadly divided into two parts as the upper coastal plain and the lower coastal plain. The boundary between the upper and lower coastal plains is clearly defined around the 40-50 m elevation (Fig. 3). The upper coastal plain is a dissected plateau having a maximum elevation of about 300 m. The study area is located on the lower coastal plain. The lower coastal plain is noted for a thick layer of sediment, as has been found in the floodplains of the major rivers in this sector, and these de-

posits extend to a depth well below the present sea level (Cooray, 1984; Erb, 1984; Wadia, 1941). The flatness of the terrain owes mainly to the filling-up of valleys by fluvial sediment. The thickness of the alluvium is highly variable. The agents that transported these sediments could be marine, aeolian or fluvial depending on their geographic location and stratigraphic position.

Topography of the Study Area

The general topography of the floodplains and the surrounding area can be described as a rolling plain with the elevation ranging from the sea level to about 50 m above msl. The high grounds of the terrain are the residual hills, which are located on either side of the North-South running Kepu Ele/Bolgoda Ganga and to the South of the Kalu Ganga. The residual hills extend from the South of the Kalu Ganga towards the North forming a barrier between the Bolgoda Ganga/Kepu Ele valley on the East and the shoreline on the Western side. This barrier is clearly illustrated by Figure 4. The hillocks represent remnants of a series of dissected strike ridges typical of the South-western sector of the island (Fig. 4). The lower reach of the Kalu Ganga has cut its present channel through these residual hills. The topography on either side of the Kalu Ganga below the Kepu Ele is relatively rugged and

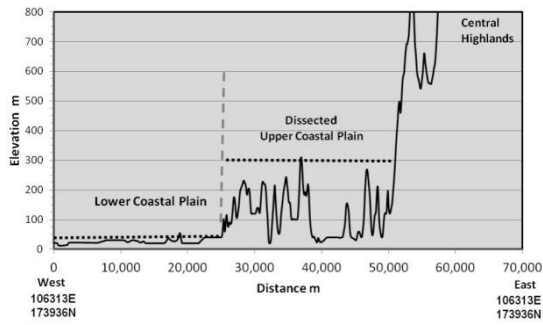


Figure 3: Break in Slope of the Southwestern Coastal Plain.

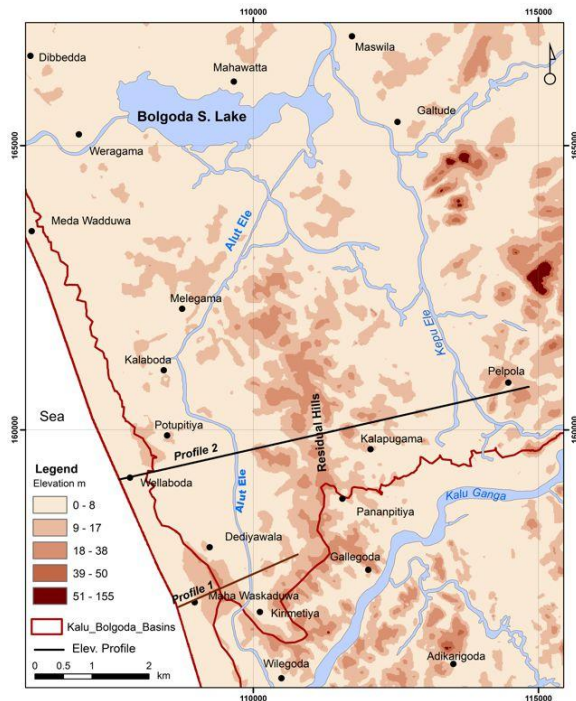


Figure 4: Topography of the Lower Kalu Ganga and Bolgoda Ganga Catchments.

there is no sign of a floodplain which is quite unusual for a river of this size. The variation in ground elevation from West to East is depicted by two East-West profiles drawn at Mahawaskaduwa and Wellabada (Fig. 4). The Mahawaskaduwa profile (Fig. 5a) shows that the elevation rises from the coast to about 22-23 m and then drops towards the Alut Ele. Again it rises on passing Alut Ele on the Eastern side. The highest point along this profile represents the summit of a residual hill. Towards the North at Wellabada, the first summit is a raised beach which has an elevation of about 7-8 m.

The elevation drops from the top of the beach ridge until it reaches the lowest point at about 3 m above msl forming a depression with lagoonal or estuarine clay deposits. From

this unit, elevation rises again towards the Kepu Ela in the East reaching up to 25 m over the residual hills (Fig. 5b). The Kepu Ele is located in a pre-existing valley which divides the residual hills unit into two parts, Eastern and Western.

The Bolgoda Ganga floodplain is situated between these residual hills. The floodplain consists of two subunits, the marshes and the higher alluvial terrace. The lower part of this floodplain is within a few meters from the mean sea level and forms a marsh in many places. The upper level forms a terrace of older alluvium deposited at the edge of the floodplain by a palaeo-river migrating across the floodplain. A former alluvial surface has undergone erosion and siltation by a powerful stream and was later silted up under estuarine conditions. The degree of dissection of the alluvial formation is clearly marked by the low-lying areas which are mostly marshes at present (Fig. 6).

Major Landform Units

The study area falling into two river basins and one inter-basin area can be divided into six geomorphological/landform units (Fig. 6). They are the modern beaches, raised beaches, residual hills, silted up lagoons/ estuaries, levées, and fluvial terraces. In addition, there are river channels and water-bodies, which are remnants of a large palaeo-river and its estuary. The origin of each of these units was inferred from the type of sedimentary deposits in the Bolgoda floodplain and their morpho-stratigraphic characteristics. The particular assemblage of landforms found in the area is a product of fluvial and marine/aeolian processes (Table 1). The distribution of these sedimentary sequences is symmetric on either side of the Bolgoda-Kepu Ele channel, with the exception of the coastal sedimentary belt on the West. The coastal sedimentary unit can be sub-divided into modern beaches occupying the lowest terrace, the Pleistocene beaches at upper terraces and the silted up lagoon. The marine sedimentary unit is bordered on the East by the residual hills near the Kalu Ganga and by a silted up lagoon in the North. The fluvial unit is made up of alluvial terraces, levées, marshes and channels.

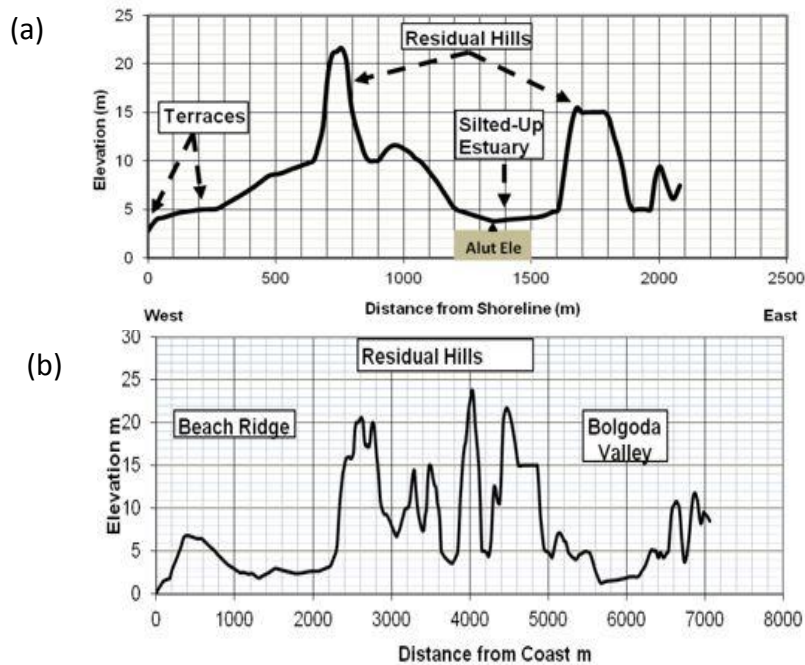


Figure 5: (a) East-West Profile at Maha Waskaduwa and (b) Cross-Section from the shoreline at Wellabada to Kepu Ele showing coastal terraces, residual hills and fluvial sedimentary unit.

The upper part of the fluvial sedimentary unit merges with the residual hills and is designated as a gently undulating to undulating plain. The hillocks forming the residual hills unit is a dissected plateau. Erosion has broken up the plateau into isolated hills emerging above the alluvium filled valleys and terraces. A well-developed levee can be found along the Kalu Ganga lower reach. The upper alluvial terrace has undergone extensive erosion since its formation, resulting in a system of valleys and isolated islands. The lower terrace represents this erosional phase. Erosion may have been caused by a river migrating across the floodplain; this river has changed course leaving the marshes of the lower terrace deprived of sediment. Only a thin layer of fine grained sediment covers the lower terrace.

Marine Depositional Terraces and Lagoons

The coastal sedimentary unit consists of recent beaches, Pleistocene beaches and silted up lagoons/estuaries. The recent beaches form the lowest terrace which is associated with the contemporary coastal processes. The Pleistocene beaches are at a higher level forming upper terrace levels or a raised beach. Behind the raised beach is found a silted up lagoon or estuary towards the North (Dediyawala) or residual hills in the South (Maha Waskaduwa). The older beaches

are a product of marine regression possibly caused by lowering of the sea level. The Eastern boundary of the coastal sand belt can be considered as the former shoreline (Fig. 6).

There are two terraces at some places at about 3-4 m and 5-8 m above the lowest levels, whereas there is only one upper terrace in others. The uppermost terrace level which merges with the residual hills in the South forms a well-defined beach ridge in the North. The Galle Road runs on the summit of this beach ridge. The surface material is loose sand without any sign of soil development suggesting its recent age. This soil is classified as Regosols Great Group in the national soil classification (Panabokke and Moorman, 1961; De Alwis, 1972). Sandy regosols are found in the coastal sand belt. The surface sand is well sorted fine grained sand with a median size of 0.6 to 0.7 mm (Fig. 7). The Geological Map (GSMB, 1996) describes the sand of the upper terraces as windblown deposits. The thickness of this layer exceeds 9 m. Examination of a dug well in Maha Waskaduwa, landward of the Galle Road, revealed that the sand at a depth of about 9 m below the surface is partially indurated (Plate 1) and has a structure similar to that of modern beach sand. The well is located at a site about 6 m above msl and therefore the bottom of the well, which has

Table 1: The Characteristics of the Major Landform Units

Landform Unit	Nature of material	Remarks
Modern Beaches	Well-sorted fine sand	Present day seasonal beach
Raised Beaches	Well-sorted fine sand	Three terraces. Sand at depth is partially cemented. Surface material may be wind-blown sand.
Residual Hills	In-situ weathering products	They represent the highest topographic positions of the study area; has undergone laterization. They show signs of extensive fluvial erosion.
Silted-up Estuaries & Lagoons	Fine clays including ball clay deposits	Lowest topographic positions; deposition under lagoonal and/or estuarine conditions
Levees	Silty sand along the present river channel	These are over bank deposits of silt and fine sand laid down during floods.
Fluvial Terraces	Elevated fluvial sediment unit. Laterization has taken place everywhere.	The surface material of the well-drained higher terraces has undergone laterization. The sediment shows upward fining sequence. Gem gravel deposits are found lying on the weathered rock representing former channel bed. The gravel layer is separated from the overlying sand layers by an iron pan.

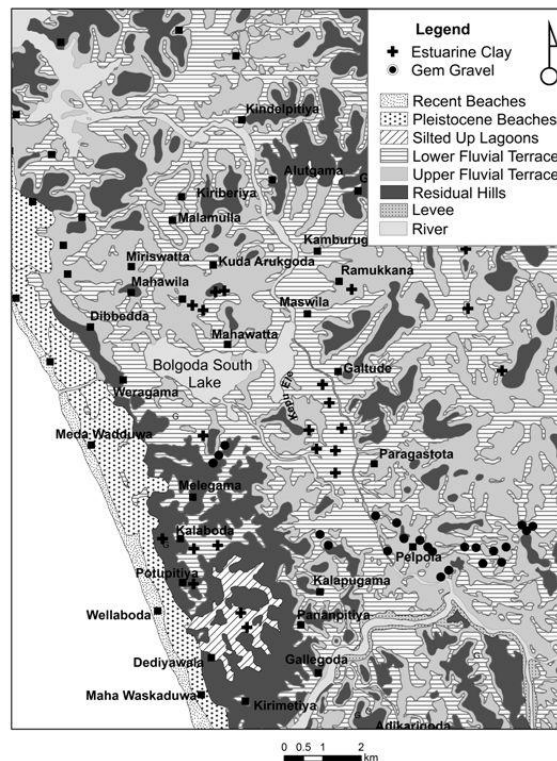


Figure 6: The Morphological Units of the Kalu Ganga-Bolgoda Lake Flood Plains.

not reached the bedrock, is already below the mean sea level (3 m). This suggests that the sand layer extends to a depth well below the present sea level. The sediment at depth clearly suggests that the former shoreline was about 1 km landward from the present position. Similar evidence is found elsewhere as well. A study of sand samples obtained from

two bore holes sunk to a depth of about 12 m at the Ratmalana Airport premises (Cooray, 1963a) also indicated that the former shorelines existed landwards of the present position. The top 6 m of the deposit is predominantly sandy and similar to the coastal sands. There would have been a much wider belt of coastal sands along the Southwestern coas-

tline before the modern phase of coastal recession set in.

Fluvial Sedimentary Unit and Its Stratigraphy

The fluvial sedimentary unit forming a floodplain situated on either side of the Bolgoda Ganga/Kepu Ele can be divided into two subunits based on elevation and age. They are the upper and lower fluvial terraces. The upper level forms a dissected depositional plain of older sediment bordering the residual hill region along its Eastern and western borders. The lower terrace is of more recent and erosional origin. This unit is described in the geological map of the area (GSMB, 1996) as estuarine clay. Although the top layers of the sediment are clays, pockets of coarse sediment containing sand, gravel and larger particles are found below it. The gem gravel is mined at many locations in the area. These gravel beds located at various depths from near surface in marshes to about 10m below the surface on high ground are known to contain precious stones similar to those found in the Ratnapura area.

The lowest elevations of this unit are the water-bodies. The largest of the water bodies are the two freshwater lakes, Bolgoda South and North Lakes. From the topographic maps it is clear that the bottom of these water bodies is situated below the present sea level. The water bodies are inter-connected by a network of natural and man-made channels and this system is connected to the sea by a narrow winding channel which enters the sea at Panadura and a canal to the sea from the Bolgoda South Lake. The Bolgoda Ganga is clearly a remnant of a much larger palaeo-drainage system.

The stratigraphy of the sediments of the fluvial terraces (upper and lower) shows several episodes of sedimentation (Fig. 8). The base on which sedimentary deposition has taken place is a kaolinized bedrock surface which represents the bed of the channel of a large palaeo-river. The gravelly bed-load has been laid down on the channel bed. Deposition of bed-load may have occurred as channel bars in the middle of the channel, or as point bars inside meander bends. The sediment in the gravel layer is poorly sorted, and its texture ranges from clay to large boulders. The large size of the quartzite boulders (occasionally with a diameter over 70 cm) and the high level of rounding indicate that they have been transported long distances by a river with a high level of competence. The stratigraphy of the sediments of the fluvial terraces (upper and lower) shows several episodes of sedimentation (Fig. 8). The base on which sedimentary deposition has taken place is a kaolinized bedrock surface which represents the bed of the channel of a large palaeo-river.

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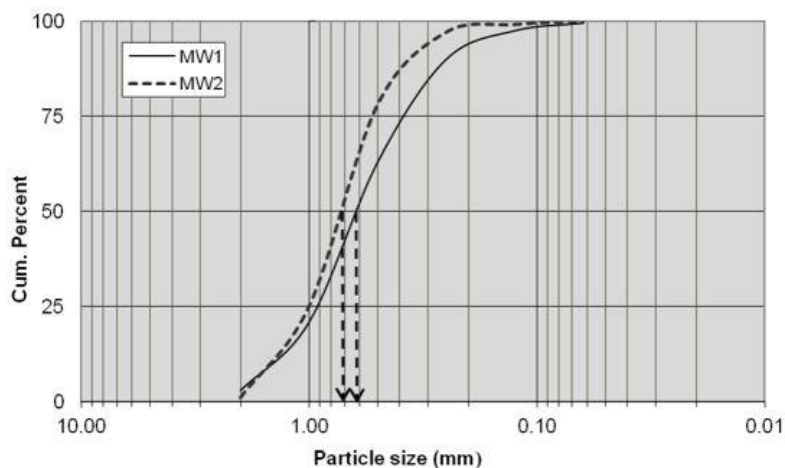


Figure 7: Textural Characteristics of Sand from the Raised Beach (Maha Waskaduwa)

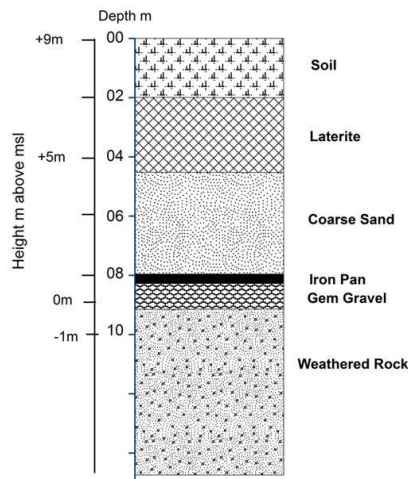


Figure 8: Stratigraphic Section of the Upper Fluvial Terrace at Pelpola.

Similar gemstone placer deposits described from the Ratnapura area and elsewhere are considered as relatively young belonging to the late Quaternary period (Gunatilaka and Almond, 2001). At Pelpola, the elevation of the land surface is about 9 m above msl, and the bottom of the gravel layer is at about -1 m from msl. This is about the same bed elevation of the present Kalu Ganga in the lower reaches. The gravel layer is found at a lower elevation in the marshes. Thus, the Pelpola and other high level gem pits represent a fluvial terrace. Similar terraces have been described by Cooray (1983) in the Malwana area of the Kelani Ganga.

The pebbles, cobbles and boulders in the gem gravel are set in a matrix of sand and clay. The finer materials, sand, silt and clay, would have been deposited between larger gravels filling the voids between them. The largest boulder, found among gem gravels at a heap of discarded gravel of a gem mine at Pelpola, had a diameter of 70cm and is well rounded. The stratigraphic column shows an upward fining sequence of sediment. This indicates that the competence of the river changed significantly during this time due to the rise in the sea level. As the sea level began to rise the lower reaches of the river were inundated by brackish water. The gravel layer is situated about 8 to 9 m below the present land surface of the high grounds in almost all the pits examined. The sand layer above the gravels is overlain by silty and clayey lateritized material of several meters in thickness. The sedimentary sequence is a product of the deposition within the river channel itself or as

overbank deposits. The finest material can be described as overbank sediment carried in suspension and estuarine deposits.

A majority of the gravel of all sizes was well rounded quartz indicating a long distance of transport (Plate 2). Quartz is one of the most resistant to wear and tare, and therefore does not get rounded easily. The quartz pebbles found in the gem deposits may have been derived from the quartz veins in the upper Kalu Ganga basin. It is also interesting to note that the types of gems found in these deposits are very similar to those found in the Ratnapura region (sapphire, rubies) but they are smaller in size and free of defects. Evidently this is due to the longer distance of transport. These gravels are similar to terrace gravel described by Deraniyagala (1958) and Cooray (1963b). The gravel layer is overlain by an iron pan which is also found in association with the Erunwala gravel deposits and has been identified as ferricrete (Cooray, 1963b). Iron crusts or iron pans are formed in the zone of groundwater fluctuation. At present, the iron pan is situated at a depth of about 8 m, well below the permanent water table. This suggests that the water table at the time these deposits were laid down was much lower than today. This is possible only under conditions of a much lower sea level and drier climatic conditions. It is well established that the Quaternary had many glacial and inter-glacial cycles. The glacial periods were known to have been associated with arid/semi-arid conditions and interglacials humid conditions in the tropics. This is attributed to the weakening and strengthening of the Southwest monsoon circulation. The onset of the humid period following an arid phase signifies intense erosion under sparse vegetation cover (Gunatilaka and Almond, 2001).

On top of the iron pan, there is a layer of coarse sand signifying a change in the sedimentary environment. This points to a sedimentation phase in the river under greatly reduced competence which is no longer capable, even under flood conditions, of transporting large pebbles, cobbles, and boulders of the size found among the gem gravels. The thickness of the sand layer is about 8-10 m and the upper part of the upper terrace sand layer has undergone laterization and soil development. The surface soil layer belongs to the Red Yellow Podzolic Soils (RYP) Great Group. This is a

well-developed older soil found in the fluvial terraces as well as the residual terrain.

The textural characteristics of the terrace sand from Pelpola are given in Figure 9. The sand is poorly sorted compared to moderately well-sorted coastal sands and has a median size of 0.7 mm. Nearly one-third of the sand is coarser than 1.0 mm. As can be seen from Figures 7 and 9, the grain size curves of coastal (Maha-Waskaduwa) and river sands (Pelpola) are distinctly different. The shape of the grain size curve indicates the degree of sorting, where well-sorted sands will have S-shaped curve.

Residual Hills and Valleys

This unit is of erosional origin and extends as a belt in a SSE-NNW direction on the Western part. It has been described in the past as a Rolling Upland Planation Surface (Somasiri, 1999). The hillocks have rounded crests typical in humid tropical climates. Erosion would have occurred under a drier seasonal climatic regime and therefore this unit can be considered a relict feature. The shallow valleys are typically broad. The superficial material has undergone laterization. As in the case of the terrace sand, Red Yellow Podzolic soils have developed in the residual hills unit as well. The parent material of these soils has been derived from the weathering of the basement rocks of the area. Red Yellow Podzolic soil is a mature soil indicating that it is an older land surface. This also supports the hypothesis that this unit is a relict feature, a product of past erosion under a different climatic regime.

Kalu Ganga Valley and the Levees

The present bed of the lower reaches of the Kalu Ganga is below sea level up to a distance of about 37 km from the mouth near Holambakanda (Fig. 10). The depth near the

outfall is in excess of 2.5 m below the sea mean sea level. The riverbed elevation is also highly variable in the lower part up to about 30 km upstream from the outfall. The channel bed elevation of all major rivers is below sea level in the lower reaches. This has been interpreted as evidence of drowning of the lower reaches of the streams by the rising sea level. Similarly, the low bed level of the lower Kalu Ganga indicates that the river has undergone drowning. This is further supported by the presence of well-developed levees in the lower reaches of the Kalu Ganga (Fig. 11). Formation of levees is associated with aggradation. This is caused by the loss of the capacity of the river to transport its bed-load due to the reduction of the bed slope due to the elevation of the sea level.

Change in Drainage Pattern

In response to rise in the sea level during the Holocene period, the drainage pattern of the Lower Kalu Ganga and Bolgoda Ganga catchments has undergone drastic changes. The main change is the change in the direction of the flow of the Kalu Ganga abandoning the former course (Fig. 12). As a result, the lower Kalu Ganga basin developed into a separate basin with the remaining parts of the river network. The new course of the Kalu Ganga cuts through the residual hills unit. However, the Kalu Ganga has not completely separated from its former course. At times of floods, Kalu Ganga water enters the Bolgoda catchment.

As can be seen from the distribution of gem mines, the course of the palaeo-Kalu Ganga has changes across the floodplain considerably. Its palaeo-connection with the Bolgoda basin can be traced between the dashed curves on Figure 12. The river course has shifted laterally depositing its gravelly bed-load over a large area.

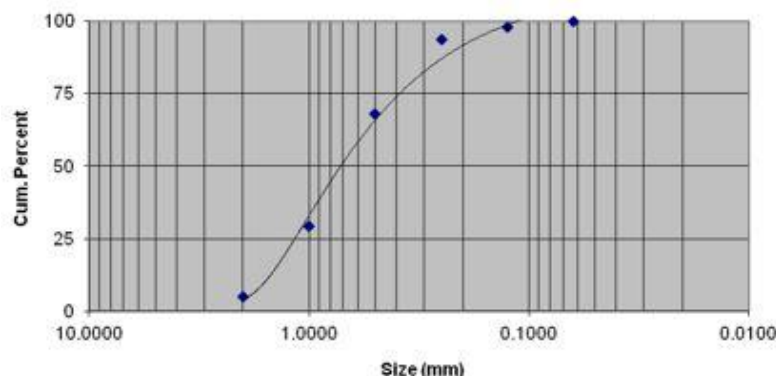


Figure 9: Textural Characteristics of Sand in the Fluvial Sediment of the Alluvial Terraces.

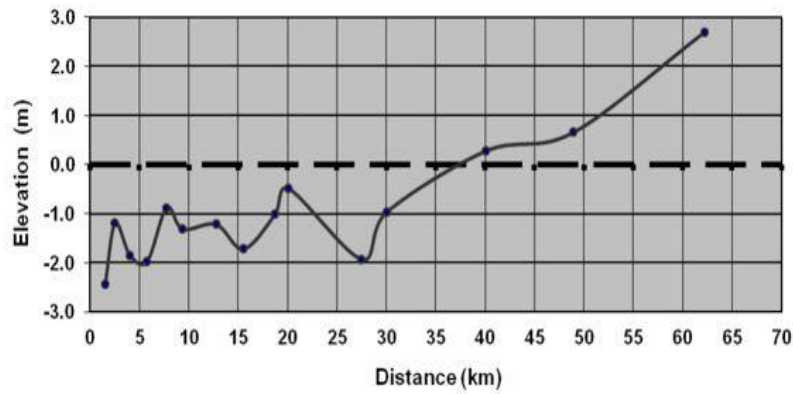


Figure 10: River Bed Elevation Profile of the Lower Kalu Ganga.

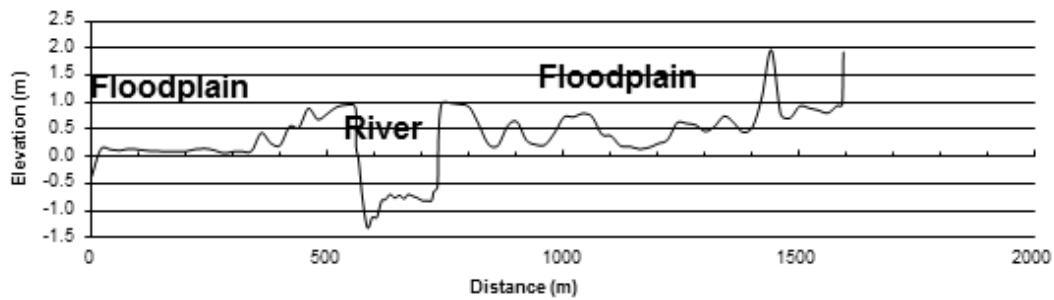


Figure 11: Cross-Section of the Kalu Ganga at 9.34 km Up-stream (Data Source: Unpublished records of the Irrigation Department).

CONCLUSIONS

The drainage pattern of the area under study appears to have drastically changed in the recent geological past. It is quite clear from the foregoing evidence that the Bolgoda Ganga basin was a part of the Kalu Ganga basin, which later assumed a separate identity. This explains much of the anomalies relating to the Bolgoda basin and its drainage pattern. The gem gravel deposits on alluvial terraces, and the North-South valley represent the former courses of the Kalu Ganga. What is left of the lower reaches of the former Kalu Ganga is the Bolgoda Ganga (Panadura Ganga in the lower reaches), the two lakes and silted up parts of the estuary in the present Bolgoda catchment.

The size of the estuary and the caliber of the bed load suggest that the Kalu Ganga carried much more water at the time and had a steeper slope. The size of the gravel indicates that the river that transported the gravel should have a much larger flow or steeper gradient than the present Kalu Ganga which basically flows below sea level in the last 37

km or so. A steeper gradient is possible only if the sea level was much lower than today.

It may also be possible that a wetter climatic phase with more frequent floods and a steeper gradient may be responsible for the transportation of gem gravels to this area. The change from a gravel bed load to the present more sand-size bed-load of the Kalu Ganga may be attributed to a climatic change and associated sea level rise. This resulted in the fining upward sequence of sediment. The top layers of sand testify to this change. These sands are very similar to the caliber of the bed-load carried by the Kalu Ganga at present.

The Lakes in this catchment have elevations below the sea level. Two small streams that flow into the lakes could not have developed such a large estuary covering an area of about 18.9 km². Size of the estuary is ever larger when the silted up areas are also taken into consideration. The former channel of the Kalu Ganga in the Bolgoda basin is now silted up possibly by the floodwater escaping from the Kalu Ganga through the gaps in the ridge separating the two basins.

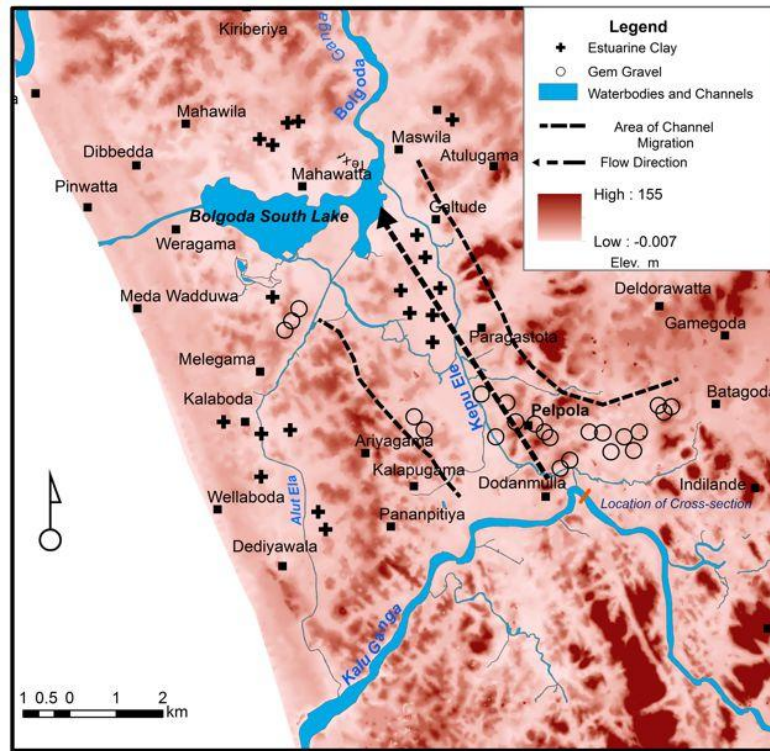


Figure 12: Palaeo-Drainage of the Bolgoda-Kalu Ganga floodplains.



Plate 1: Beach Sand at the Bottom (9m) of a Wellin MahaWaskaduwa.



Plate 2: Rounded pebbles in Pelpola area.

The similarity of gem gravels found in the Bolgoda basin to those in the Ratnapura area in the Kalu Ganga basin further suggests that the Bolgoda floodplain is in fact the former floodplain of the Kalu Ganga. Absence of gem gravels in the adjacent basins to the North or South further evidence of such a scenario. Therefore, the source of gem gravel of the Bolgoda lake is possibly the same as that of the Ratnapura beds, its transportation was done by the Kalu Ganga. The fact that the long profile of the lower reach of the Kalu Ganga up to 55 km upstream is below the sea level indicates that it is a drowned river valley. This drowning is most likely to be a result of the rise of sea level rather than subsidence.

One may speculate that the offshore canyon situated off the Bolgoda Ganga outfall is a product of a large terrestrial river. The canyon may represent the lower course of the palaeo-Kalu Ganga and/or a product of turbidity currents generated by the river. When the sea level was about 100 m below the present level, the lower parts of the streams occupied the continental shelf. This is the most likely way the Panadura canyon was produced.

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REFERENCES

- Cooray, P.G. (1963a) Size and Sorting in Some Recent Coastal Sands from Ceylon. *The Indian Mineralogist* 4: 14-28.
- Cooray, P.G. (1963b) The Erunwala Gravel and probable significance of its ferricrete cap, *Ceylon Geographer*, 17: 39-48.
- Cooray, P.G. (1984) *An Introduction to Geology of Sri Lanka (Ceylon)*, 2nd Edition, Colombo, National Museums of Sri Lanka.
- Coconut Research Institute (Undated) *Soil Map of the Horana and Panadura Sheet*, Lunuwila, CRI.
- Deraniyagala, P.E.P. (1958) *The Pleistocene of Ceylon*, Colombo, National Museums of Sri Lanka.
- De Alwis, K.A. (1972) *Handbook of Soils of Sri Lanka*, Colombo, Soil Science Society.
- Dyre, K. R. (1997) *Estuaries, A Physical Introduction*, 2nd Edition, Chichester, Wiley.
- Erb, D.K. (1984) Landforms and drainage. In: Fernando, C. H. (ed.), *Ecology and Biogeography in Sri Lanka*, Dr. W. Junk Publishers, The Hague, 35-63.
- Fairbridge, R.W. (1961) Eustatic changes in sea level, *Physics and Chemistry of the Earth* 4: 99-185.
- GSMB (1996) *Colombo-Ratnapura 1:100,000 Geological Sheet (Provisional Series)*, Colombo, Geological Surveys and Mines Bureau.
- Gunatilaka, A. and Almond, D.C. (2001) Serendipity and the Jewels of Serendib- Part 2. External Processes and Climatic Framework that Influenced the Genesis of the Multi-Species Gemstone Province in Sri Lanka, *Journal of the Geological Society of Sri Lanka*, 10: 59-67.
- Katupotha, J. (1995) Evolution and the Geological Significance of Later Pleistocene Fossil Beds of the Southern Coastal Zone of Sri Lanka, Colombo, NARESA.
- Kidson, C. (1986) Sea-level changes in the Holocene. In O. van der Plassche (ed.) *Sea-level research: a manual for the collection and evaluation of data (Norwich)*, 27-64.
- Moorman, F.R. and Panabokke, C.R. (1961) *Soils of Ceylon: A New Approach to the Identification of the Most Important Soil Groups of Ceylon*, Tropical Agriculturist, cxvii (1): 1-67.
- Premathilake, R. and Nilsson, S. (2001) Pollen morphology of endemic species of the Horton Plains National Park, Sri Lanka, *Grana* 40: 256-279.
- Somasiri, S. (1999) Physiography and Landforms, In: Mapa, R. B., Somasiri, S. and Nagaraja, S. (Eds.), *Soils of the Wet Zone of Sri Lanka*, Special Publication 1, Peradeniya: Soil Science Society of Sri Lanka. pp. 14-22.
- Swan, S. B. (1983) *An Introduction to the Coastal Geomorphology of Sri Lanka*, Museum, Colombo.
- Weerakkody, U. (1988) Mid-Holocene sea level changes in Sri Lanka, *Journal of National Science Council of Sri Lanka* 16: 23-37.
- Weerakkody, U. (1992) The Holocene Coasts of Sri Lanka, *The Geographical Journal* 158(3): 300-306.
- Wadia, D.N. (1941) The Beira Lake of Colombo, its fluctuations and relation to recent changes of sea-level, *Journal of the Royal Asiatic Society (Ceylon Branch)* 35(64): 91-96.