Stratigrafical Sediments and Paleo-Climate Changing Patterns in Kalu Ganga River Basin in Rathnapura of Sri Lanka

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Abstract

Geologically, Sri Lanka is an important place to study the erosion, transportation and deposition process of river flows. According to the geological time scale, these processes were evident during the quaternary period in Sri Lanka. Therefore, lots of sediments found within the low lands area around the country. The sediments were deposited around the country by the process of river erosion and transportation. The Kalu river basin is prominent for sedimentation of such river basins when compared with other river basins. It is in the Rathnapura district that high deposition has taken place. There is a stratigraphy in many types of sediment in the Kalu Ganga basin in terms of the depth of sediments and number of layers. This research has attempted to study the way in which the above mentioned stratigraphy has taken place and which factors have caused the creation of such particular patterns. For this purpose, an investigation was carried out in 10 gem mines representing the lower catchment of the river through random sampling. GIS mapping, laboratory testing and statistical methods have been used for analyzing and presenting data. Research results brought out very important findings in relation to the stratigraphy of sediments layers in the Kalu Ganga river basin. There was a spatial variation in the number and the depth of gem bearing sediment layers. Since the lake sediment layers are found in the lower catchment, it is suggested that there was paleo climate change during the Quaternary period.

Key words: *Sediment layer, Deposition, Kalu river, Stratigraphy, paleo-climate change*

Introduction

The term sedimentology has been defined by Wadell (1932) as "the study of sediments". Similarly this term has also been defined by Sukhtankar (2004) as "sedimentology is the science of sediments". In Chamber's Dictionary (1972), Sediments have been defined as "What settles at the bottom of a liquid as a deposit".

Sedimentology also includes the study of chemical precipitates, like salt, as true detritus deposits. The boundaries of sedimentology therefore appear to be diffuse. According to Sukhtakar (2004), in earth science, three different terms that are related to the study of sediments are commonly encountered. However, each has a different connotation and deals with different aspects of the scientific study of sediments. These three terms are Sedimentology, Sedimentary Petrology and Stratigraphy.

Sedimentology essentially includes the study of the natural processes such as erosion and weathering, which are responsible for the origin and types of sediments. Other major aspects deal with the study of agents responsible for the transportation of sediments. Thus, sedimentology essentially includes the scientific study of sedimentary processes, but excludes the subject of digenesis. The basic constraint to sedimentation is the range of rock types in the area supplying material to the sediment. Within this constraint a wide range of variation may occur depending on the ability of the various types to survive the processes of transportation, deposition, and subsequent re-weathering. As a result of this, the lithology of sediment rarely and precisely reflects the geological composition of its source area (Allen & John, 1984). Stratigraphy is a branch of geology which studies rock layers (strata) and layering (stratification). It is primarily used in the study of sedimentary and layered volcanic rocks. Stratigraphy includes two related subfields: lithologic stratigraphy or lithostratigraphy, and biologic stratigraphy or biostratigraphy (https://en.wikipedia.org/wiki/Stratigraphy-10-06-2016).

A consideration of the general features of the geology and climate of Sri Lanka helps to establish the prevalence of gem-bearing areas. Sri Lanka is a tropical Island and lies 32 Km to the east of the southernmost extremity of peninsular India. It has an area of 65,600 Sq. km and is 432 km long and 224 km wide at its greatest breadth. The island may be divided into two main physiographic divisions,

1. The low-lying coastal plain with little relief is traversed by rivers which have reached their base of erosion.

2. The central highland with an immature drainage pattern and marked relief abounds in numerous strike ridges, hills and mountains (Herath, 1984).

Sri Lanka lies in the monsoon regions of south-east Asia and it has a humid tropical climate. The division into a west zone and a dry zone which merge in an Intermediate zone is one of the most conspicuous geographical features of the Island. The rainfall pattern is shown clearly demarcating the west and dry zones. The average rainfall varies from below 1270 mm in the north-west and south-east parts of the lowland zone to over 5080 mm in the south-west slopes of the central hill country. The mean rainfall for the Island is 2032 mm. In the west- zone area the average mean temperature varies between 21°C–29°C and in the dry zone it may be nearer 32°C. In the highland the mean temperature ranges between 15°C–26°C according to elevation (Herath, 1984 & Chandrapala, 2007).

Over 90 Percent of the surface area of the Island is underlain by Precambrian rocks consisting of a complex series of high-grade metamorphic rocks, most of which have been divided from sediments and altered by one or more metamorphisms. Associated with these metamorphic rocks are granites and granitoid rocks of igneous origin (Herath, 1984).

In the Earth's history there were five major glaciations, namely, the Huronian, Cryogenian, or Sturtian–Varangian, Andean–Saharan, Karoo and the Quaternary that occurred between 2300 and 0.0114 Ma (Katupotha, 2013). Climate changes and variation in sea level which followed the glacial cycles from Huronian glaciations to Karoo glaciations continued creating lots of geomorphological landforms. The mean sea level in these periods of glaciations had fluctuated and it might have been the major cause of deposition of gem bearing sediment layers at different depths from the Pleistocene to the recent Epoch.

Long-term (400–200 Ma), low natural denudation rates (8–18 mm kyr−1) are also known from tectonically stable monsoon regions such as Madagascar and Southern India (Seward et al., 1999; Gunnell and Louchet, 2000). These regions of former Gondwana ancestry (which include the Lutzow-Holm complex in Antarctica) have similar geological and thermo tectonic histories (Pan-African), similar lithologies (granulite facies rocks), mountain relief, high rainfall intensity and landslide activity, prolific Quaternary gemstone placer deposits and even similar gemstone compositions (Almond and Gunatilaka, 2001), and a case for a Pan-African mineral belt linking Madagascar, Southern India and Sri Lanka has already been established (Dissanayake and Chandrajith, 1999). Cosmogenic nuclide measurements confirm the relatively very young age of the placers (Gunathilaka, 2007). Several studies show a late Pleistocene to Holocene age for the placer deposits (Deraniyagala, 1958; Gunatilaka and Almond, 2001).

Methodology

The primary and secondary data collection methods that have been applied in data collection and quantitative methods have been used for analysis of data. For each method except the core pretreatment and description, a reproducible report on the laboratory procedures is preceded bya brief explanation of the method's, its benefits for paleo-environmental research. The Kalu Ganga basin was divided into mainly three phases based on elevation;

Upper catchment
Middle catchment and
Lower catchment area

The Lower catchment has been selected in the sampling process and 10 gem mines were very carefully selected natural undisturbed mines for collection of primary data. The random method of sampling was used in this research to select the gem mines. Since gem mines of the area varied from 15 meters to 20 meters in depth from the surface, some particular attributes were considered for selection of gem mines such as thickness and depth of sediment layers, variety of minerals, shape of minerals, type of minerals, size of minerals etc. Five mines were very carefully selected for analysis of grain size. Sediment samples were collected using gem mines. Collected sediment samples of lowest level gem bearing deposit were measured for their particle size from using Sieve analysis and Pipette analysis methods. The depth and thickness of the layers were measured and the constituents of the layers were identified. Stratatigraphy of the profiles were plotted on the basis of these analyses. The sieve analysis is performed to determine the distribution of the coarse fraction. Grain size distribution was used to identify sedimentary processes.

Results and Discussion

The lower catchment shows deep stratigraphy. It has a brownish to yellow loose topsoil layer. Beneath this is a sandy clay layer. This layer is about 3 m in depth. Below this there is a sand and rock fragment layer. Below this is a layer of black mud. The gem-bearing layer is situated below this. Beneath this gem-bearing layer of lateric earth is to be found. Further below this, successively there are a sandy clay layer, a sand layer with pebbles and cobbles, a black mud layer, a gem-bearing gravel layer, lateric clay layer, a layer of sand with pebbles and cobbles, and a lower gem-bearing sediment layer. Beneath all this lies the weathered bedrock. It is only rarely that shows three gem-bearing layers in the lower catchment. Another unusual feature is the presence of black mud layers. However, two layers of black mud are not commonly found. However, at least one layer of black mud is a common feature in the lower catchment.

The stratigraphy of the top soil layer is shown in Figure 1.2. According to this a brownish to black topsoil layer exists in the upper catchment and a brownish to yellow topsoil layer in the lower catchment. A brownish to yellow loose topsoil layer and a sandy soil layer with weathered rock fragments of pebble-to boulder-sized particles exists as a very deep top layer in the middle catchment.

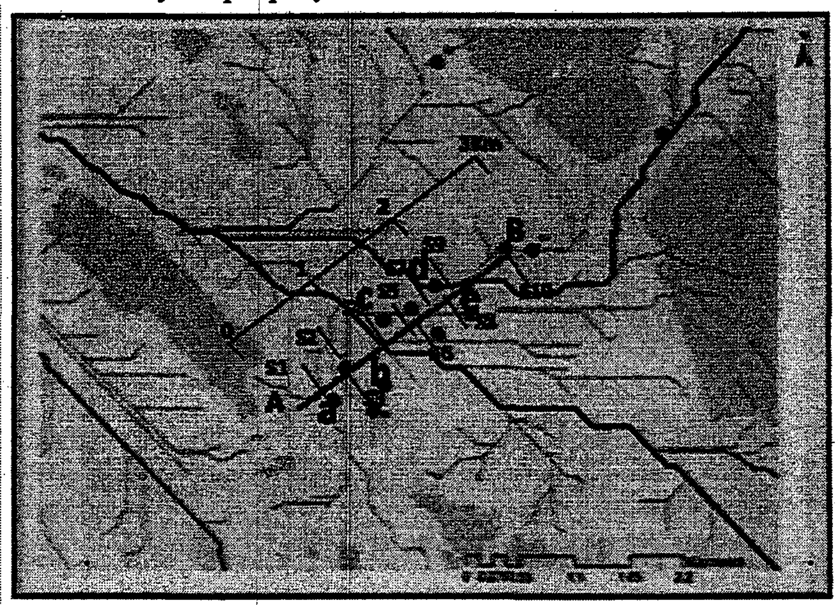

Figure 1.1-Locations of sediment Samples collected in a cross-sectional Area (from A to B) in the lower catchment of Kaluganga basin. (S1 to S10 are gem mines and from where the samples were collected for analysis)

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Stratigraphy of A-B cross section

The Absolute Location of the area demarcated by the cross-section A-B is between 157569.3634mN and 157543.952mN and 161330.2522mE and 165704.6mE. Gem-mines are widely spread in this area. The average depth of these mines is 18 m to 20 m and the sediment layers are in varying thickness. While the way that the strata are positioned is similar in most mines, their depth and thickness vary. While the surface layer consists of brownish to yellow loose soil, below it there is a layer of sandy clay. Its thickness is 1m to 2 m. beneath this, there is a layer consisting of sand and rock fragments. Underneath this is a layer of black mud with clay. Alongside this mud layer and below, it is the gem-bearing gravel layer and the thickness of this gem layer and that of the mud layer vary from place to place.

Further below and in sequence lie sandy clay, pebbles with a sand layer, a black mud layer, a gem-bearing sediment layer, and weathered bedrock. The special feature here is the presence of two clay layers next to gem-bearing sediment layers.

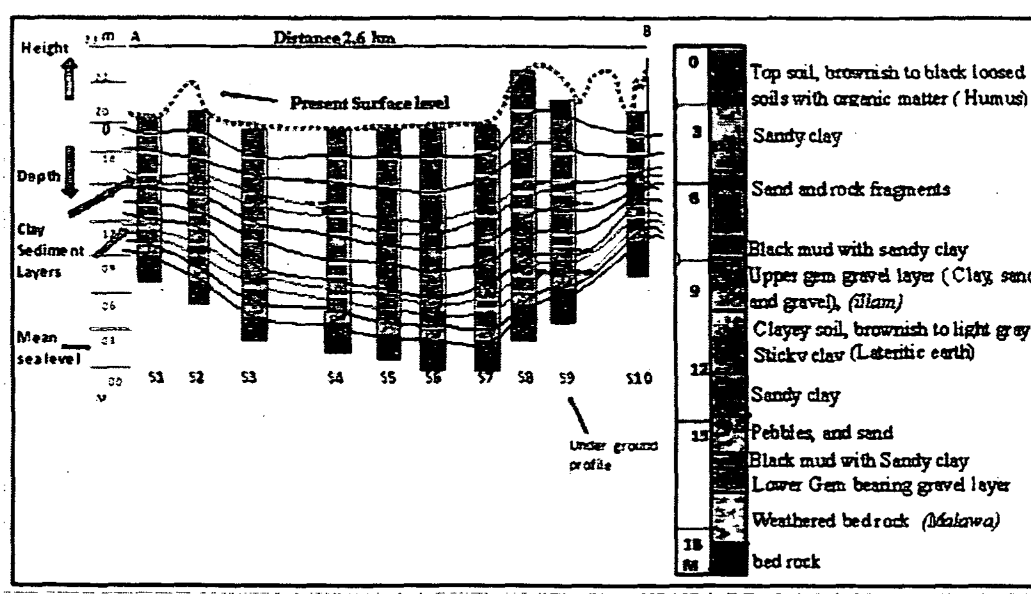

Figure 1.2-Stratigraph of the cross-section from A-B in the lower catchment of the study area.

The stratigraphic cross section between A to B shows, multiple layers of clay and gem gravel beds. Alternative layers of black mud sandy clay and gem gravel layers indicate that depositional environment has been changed over the time with some cyclic manner. Other significant feature observed in the cross section is beds are thicker in the center of the cross section while the clay content of the bed is also increased. The cross section can be considered as a section across a basinal structure and it might be a paleo-lake. Thus the deeper central part is calmer and deposition is the main function of the water column and deposit mostly fine grain sediments. The edges of the cross section i.e., boundary of the paleo-lake led to more agitate conditions with less deposition and coarse grained sediments. From the figure 1.2 stratigraph it is evident that two gem-bearing gravel layers and two clay layers can be identified. Bordering the lowest clay layer (01) and below it there is a gem-bearing gravel layer. In like manner, just below clay layer (02) there is a gem-bearing gravel layer (*illam*). Further there are layers of sandy clay, lateritic layer, pebbles, mixed with layers of sand and rock fragments. From this, it is possible to note learly the climate changes that have occurred in the past.

Precipitation has been reported as one of the most important factors caused to the gem bearing sedimentation process. The rainfall in the study area occurs due to a number of phenomena, namely the south-west monsoon, the inter-monsoon, depressions, and cyclonic activity. Rainfall due to the monsoons and inter-monsoons convection follows a regular pattern of precipitation distribution. However, the latter phenomena could occur at any time setting the regular pattern of convectional and monsoonal precipitations.

The research data obtained from the various modes of investigation carried out in the course of the study have revealed significant facts regarding the geological history of the study area. In particular, study of the Paleo-climate shows that within the study area, the South-western region has experienced periods of extremely heavy rainfall, periods of drought, and calm periods at different times.

The stratigraphy in the lower catchment from the Lower Quaternary to the present reveals changes in climate that have taken place. There have been changes from extreme drought to extremely heavy rainfall. According to the stratigraphy, gem-bearing sediments have been deposited during a period of heavy rainfall. Clay layers have been deposited during a calm period. From the stratigraphic study conducted in the lower catchment, the question arises as to whether the layers identified in the stratigraph were layers deposited in the Quaternary Period. According to this the climate has changed from periods of drought to periods of extremely heavy rainfall. These climatic changes could have had a significant effect on such phenomena as global warming, glacialization, and changes in sea level.

Conclusion

There have been many geological studies regarding gem-bearing sediments. However, the spatial distribution patterns and the reasons for their existence have not been investigated from a geographical perspective. Therefore the present research was undertaken to fill in this vacuum and is for this reason extremely significant.

Samples of gem mines were selected randomly but covering natural formations from these catchment in order to cover the study area. The primary data for this was obtained from field studies and some data created through laboratory testing. Secondary data was obtained from published research articles, books, and maps and tables.

In the lower catchment, gem-bearing and non-gem-bearing sediments have been deposited as layers or lenses. The thickness of the total strata together exceeds 20m and stratigraphic analysis reveals about ten layers which have been deposited at various times under various climatic conditions. The differences in the width of these layers could be the result of the slope of the basin, the quantity of river sediments, and climatic factors.

Analysis of the strata of samples from the gem mines in the lower catchment shows the presence of both gem-bearing and non-gem-bearing sediment layers. Some very significant aspects of geological history are revealed by these analyses. Especially, of the non-gem-bearing sediment layers, the clay layer is very important because in the lower catchment, in locations where the sediment samples from the A-B profile were tested, two clay layers were discovered. When a grain-size analysis of the clay samples was done, it was found that they resemble lake sediments. On this basis it can be concluded that there had been a lake in this area earlier and later in the Middle Quaternary Period.

It was found that immediately below the two clay sediment layers there are gem-bearing sediment layers. This clearly shows that after a long drought, there had been a period of extremely heavy rainfall during which the gem-bearing gravels had been transported and deposited. Later, a calm period had ensued, resulting in the existence of a lake. Although this was a calm period changes in rainfall levels are indicated by the presence of 30-40% of sand being included in the clay samples. This conclusion is supported by the grain size analysis.

The other non-gem-bearing sediment layers are the result of the climate changes that occurred in those periods. The periods of deposit of the strata can be assumed on the basis of relevant research and the geological time scale. However precise estimates of the time periods can only be determined by age-dating of the samples.

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