Total organic matter, carbonate, and grain size determination in two east-west coring transects, Luiche and Malagarasi River Deltas, Lake Tanganyika, East African Rift Valley.

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Introduction

Lake Tanganyika is a 9-12 Ma (Cohen et al., 1993) rift lake situated in the western branch of the East African Rift Valley. The geomorphology of the lake and its tributary rivers is largely determined by tectonic features associated with rifting. The Malagarasi River is a well-integrated, meandering stream system that drains much of western Tanzania (Tiercelin, J.J & Mondeguer, 1991) and is the largest sediment contributor to the lake in the Central Kigoma Basin (Tiercelin et al., 1994). The Luiche River is also a meandering stream system, but its extent and drainage is much smaller than that of the Malagarasi. The character and distribution of sediments in the river deltas are controlled by fluvial geomorphology, drainage size, source area lithology, and tectonic structure of the depositional basin. The differences in the geomorphology, drainage size, and depocenter structure between the Malagarasi and Luiche Rivers result in contrasting sediment character and distribution in the two river deltas. Consequently, sediment cores collected from similar water depths at each of the deltas will differ significantly in grain size, percent organic matter (OM) and percent carbonate (CO$_3$).

Geologic Setting

The Malagarasi River drains a large portion of western Tanzania and is the largest river entering the Tanganyika basin (Tiercelin et al., 1994). The Malagarasi River Delta is a birds-foot delta and has a prodelta area extending down to 1150m depth (Tiercelin & Mondeguer, 1991). Approximately 2.5m of sediment are exposed along the banks of the Malagarasi suggesting that the river is currently incising. The width of the river varies considerably, but is between 30-40m in most places. By comparison, the Luiche River is a meandering system with a minor drainage area of 1065km$^2$ (Cohen & Palacios, 1998). The outlet of the Luiche River is a marshland, and the Luiche system is orders of magnitude smaller than the Malagarasi system.

The Malagarasi and Luiche River Deltas are located near the region of Kigoma, Tanzania, and the mouths of the two rivers are approximately 25km apart. These two systems are an ideal place to examine sedimentation processes between a major (Malagarasi) and a minor (Luiche) rift delta system. The two systems have the same source lithology, climate, age, and depocenter structure. The regional bedrock consists of granites, gneisses, mica schists, amphiboles and quartzites of Precambrian age (Tiercelin & Mondeguer, 1991). The climate is subhumid tropical (Soreghan, 1993). Additionally, both river deltas have similar tectonic styles defined by a large platform margin bordered to the west by a major N-S ridge. River size and drainage basin size are the influential variables affecting sedimentation within these two delta systems.

Materials and Methods

Core Collection

Two East-West transects of 2 meter gravity cores were collected from the M/V Maman Benita in the areas of the Luiche and Malagarasi River Deltas near Kigoma, Tanzania (Figure 1, Figure 2, Table 1). Nine successful cores were obtained from the platform and slope of the Luiche and Malagarasi Deltas. The geomorphology of these river deltas was examined using single-channel reflection seismic data collected during Project Tanganyika ’97 (RSMAS-University of
Cores NPG7 and NPG8 were taken along transect T-97-2C (Figure 3); NPG9 and LU1 along transect 2D in the Luiche Delta (Figure 4). All Malagarasi cores were taken in the proximity of seismic line T-97-12 (Figure 5).

Organic Matter and Carbonate

Cores were subsampled at 2cm intervals for the upper 50cm, and at 5cm intervals thereafter. Samples were prepared for analysis by drying in an oven for a minimum of 72 hours at 50° C. A representative portion of the dry sediment was transferred into a pre-weighed crucible and sample weight (A) was determined using an analytical balance. Samples were transferred into a Thermolyne 1400 muffle furnace and burned at 550° C for 2 hours to remove organic matter. After cooling in a dessicator, samples were re-weighed (B) then burned at 925° C for 4 hours to remove carbonate. The samples were re-weighed (C), and organic matter and carbonate percentages were determined as follows:

\[ \%OM = 100 - \frac{(A-B)}{A} \times 100 \]

\[ \%CO_3 = \left[ 100 - \frac{(A-C)}{A} \times 100 \right] - \%OM \]

Grain Size

Smear slides were examined for cores LU1 (depth: 62m), G8 (depth: 461m), MAL6 (depth: 41.9m) and MAL5 (depth: 615m) to assess presence/absence of diatoms and changes in grain size. Additionally, a rough estimation of grain size was determined in cores LU1 and MAL6 by wet sieving. Samples were prepared for grain size analysis by drying sediments under drying lamps. Samples were then homogenized smoothly with a mortar and pestle, weighed, and placed in glass jars. Samples observation at the microscope after this step shows that the homogenized sediments did not contain broken shells or other debris. Distilled water was mixed in with sediment, and the mixture was frozen overnight to promote deflocculation of clays. Samples were wet sieved through a standard 63 um sieve. The sandy portion was then re-dried under drying lamps, and re-weighed to determine the percentage of sand. This procedure was meant to be a rough approximation of percentage sand, due to time constraints. This procedure used to determine grain size was done to provide a rough approximation of grain size in a limited amount of time. More extensive and accurate grain size analysis should be conducted soon to confirm or not these results.

Age Control

\(^{210}\text{Pb}\) dating techniques show that sedimentation rates in the Malagarasi have been approximately 3.5mm/year since the 1960’s and approximately 1.1mm/year prior to this time (Cohen, pers.comm; unpublished data). In order to compare with \(^{210}\text{Pb}\) data, the clearly defined annual laminations of core MAL4 were counted from the top of the laminations to the core bottom. The lamination count suggests a sedimentation rate of approximately 1.3mm/year. This rate is in close approximation with the results of the \(^{210}\text{Pb}\) dating.

Results and Interpretations

Organic Matter and Carbonates

The percent organic matter and percent carbonate data obtained from the Luiche Delta Area cores show the same general trend (Figures 6A-6D). Each core has a distinct high in percentage carbonate and a corresponding low in organic matter at the top. The trend continues downcore with alternating high and low percentages of organic matter and carbonate values. The Luiche cores show peaks and lows in percentage organic matter and percentage carbonate at similar depths downcore. Distinct peaks in organic matter and corresponding lows in percentage carbonate occur at core depths of ~30cm, 60-65
cm, and ~110-115cm. Core G8 (461m) has an additional peak in organic matter and low in percentage carbonate at a core depth of 100cm. Pronounced high %CO3 values and low %OM values occur at depths of ~0-2cm, 50cm, and ~90-95cm in each of the cores. Core G8 has an additional low in %OM and high in %CO3 at the ~135cm depth.

The cores from the Malagarasi Delta also show increased percentages of carbonate values at the top of cores MAL4 (203m) and MAL6 (41.9m) (Figures 7A-7E). MAL1 (10.7m) also shows an increasing trend towards the top of the core. Core MAL5 (615m) shows a decrease in %CO3 at the top of the core. All of the Malagarasi cores excluding the deepest core (MAL5) have increased %CO3 values at approximately 50cm depth in the core. This may correlate with the %CO3 peaks that are observed at the same core depth in the Luiche Delta cores. Cores MAL4 and MAL5 show a slight consistent decrease in %CO3 below ~100cm core depth.

The mean %OM in each of the cores shows a general increase as water depth of the core increases (Figure 8). This trend occurs in both the Malagarasi and the Luiche Delta systems. The Luiche Delta cores, however, do show a slight decrease in mean %OM from cores G7 (190m) to G8 (461m). The increase in mean %OM as a function of increasing core water depth may be the result of anoxic water conditions. Anoxia results in better preservation of organic matter, as there are fewer organisms to decay the OM in anoxic environments. The increase in mean %OM as core water depth increases may also be a result of a decrease in clastic dilution. Allochthonous (terrestrial) sediments are more abundant and tend to dilute the weight percentage OM and CO3 in cores taken nearer to the river mouth. In deeper water, clastic dilution is less influential. Much of the sediment accumulation in deep water, therefore, is the result of organic-matter rich autochthonous (lacustrine) sedimentation. Preliminary assessments of smear slides from the Luiche and Malagarasi cores taken from greater water depths show a large amount of diatoms.

The mean %CO3 value is high in the 10.7m Malagarasi gravity core. The general trend of mean %CO3 in the Malagarasi and Luiche cores shows an increase in mean %CO3 until cores MAL2 (111m) and G9 (92.2m) are reached. Thereafter, the mean %CO3 values decrease as water depth increases. This trend in mean %CO3 is explained by the anoxic boundary that exists at around 100m water depth in the lake. In anoxic waters, there is a decrease in organism activity which results in a low CO3 production. Thus, carbonate precipitation decreases.

Smear Slides

The results of the smear slide analyses show that the grain size of the sediments in core LU1 (62m) is generally greater than the grain size in core G8 (461m). Similarly, the grain size of the sediments in core MAL6 (41.9m) is greater than the grain size found in core MAL5 (615m). All of the examined sediments contained diatoms, and diatoms appeared to be more abundant in the sediments taken from the deepest Luiche and Malagarasi cores (G8 and MAL5). Diatom species identification was not possible due to the limiting magnification of the available microscope.

Grain Size

Grain size data for Luiche core LU1 show a sand content of approximately 0% to be relatively consistent throughout the core (Figure 9). However, from 20cm-0cm, there is an increase in sand percentage to ~1%. Grain size data for core MAL6 indicate much higher percentages of sand, as is expected with a major river system (Figure 10). The percentage of sand in the Malagarasi core varies from ~25% to ~68%, and a cyclicity is visible throughout the core.
Percentage sand values dramatically increase from ~5% at ~35 cm core depth to ~68% near the top of the core. Assuming a sedimentation rate of ~1.3 mm/yr, the increase in sand observed in the Malagarasi core would have begun ~300 yrs B.P., and the increase in the Luiche would have begun ~250 yrs B.P. The increase in grain size correlates well with magnetic susceptibility data for the same cores (see NYANZA Project report ’99-Charles Bakundukize). Magnetic susceptibility data indicates increased terrestrial input during these intervals.

It is likely that deltas in Lake Tanganyika are prograding as the result of two factors; 1) rivers in the area have been incising since the 1877 high lake-level stand (Cohen et al., 1997) resulting in increased sediment input to the deltas and, 2) increased erosion around the drainage basin due to deforestation promotes delta progradation. Preliminary grain size results of this study indicate that delta progradation may be occurring. The Luiche core exhibits a slight percent sand increase upcore, and the Malagarasi core shows a dramatic increase followed by a slight decrease. Both cores display the general trend of increasing sand percentages upcore. The procedure used to determine grain size was done to provide a rough approximation of grain size in a limited amount of time. More extensive grain size analysis will be conducted to confirm these results.

The “Carbonate Paradox”

Of the 9 cores examined in this study, 7 have relatively high carbonate percentages at shallow depths in core. Percent CO$_3$ begins to increase at ~35 cm core depth. Using a sediment accumulation rate of 1.3 mm/yr, as estimated through an annual lamination count, a core depth of 30-35 cm corresponds to an age of approximately 270 yrs B.P. In many areas of northern Lake Tanganyika, sedimentation rates began to increase around this time as a result of anthropogenic activities (Cohen, pers.comm). Magnetic susceptibility also increases at depths shallower than 30 cm in all Malagarasi and Luiche cores (see NYANZA Project Report ’99-Charles Bakundukize) supporting increased terrestrial input. Furthermore, preliminary sand percentage distribution data displays an increase in sand upcore. These lines of evidence would seem to suggest that clastic sediment dilution should be occurring and therefore, percent CO$_3$ should be decreasing. However, the reverse trend is observed as almost all cores display an increase in carbonate percentage at shallower core depths. One possible explanation for this “carbonate paradox” follows; if clastic influx is increasing in these deltas, the production of carbonate by organisms must be increasing at an even faster rate as there is no lithologic source for carbonate in the drainage basin. Increased CO$_3$ production could result from an increase in nutrient flux to the deltas. Unusually high nutrient levels observed at the mouths of the Luiche and Malagarasi rivers (NYANZA Project Report ’99-Kamina Chororoka) support this idea.

Conclusions

The %OM, %CO$_3$, and grain size data obtained from the Malagarasi and Luiche Delta areas show that sedimentation differs considerably between these two systems. Sediments taken from the deltas at comparable water depths differ in grain size, %OM, and %CO$_3$. Both the Malagarasi and Luiche Deltas appear to be prograding based on available grain size, magnetic susceptibility, and historical data. In addition, high carbonate values at shallow core depths may indicate increased productivity as there is no carbonate present in the source lithology.
Future Research

More detailed geomorphological descriptions of the Malagarasi and Luiche delta systems need to be made. A more extensive study of grain size in the two deltas should also be conducted. A thorough analysis of grain size in the Luiche and Malagarasi deltas may provide more evidence that the deltas of Lake Tanganyika are prograding. In addition, more research needs to be done on the “carbonate paradox”. Dating terrestrial plant material within the Malagarasi and Luiche sediments would be useful for correlating a specific time period with the increases in %CO₃ observed upcore.

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References

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