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Paleolimnological Investigations

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Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)
Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)

Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement.	The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme.

Burundi: Institut National pour Environnement et Conservation de la Nature
D R Congo: Ministrie Environnement et Conservation de la Nature
Tanzania: Vice President's Office, Division of Environment
Zambia: Environmental Council of Zambia

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Executive Summary

We have conducted a high resolution paleolimnological study of cores from a series of deltas along the eastern side of Lake Tanganyika, in order to document changes in watersheds and lake sedimentology and ecology over the past several centuries. Our objective was to determine probable linkages between watershed and lake processes, and to assess the likelihood that ecological change in Lake Tanganyika has been influenced by land use practices, in particular by widespread conversion of woodland to subsistence agricultural lands.

During a major research cruise in 1998 we collected an extensive suite of cores from seven deltas along the coastlines of Tanzania and Burundi. Cores from six of these deltas (Lubulungu, Kabesi, Nyasanga/Kahama, Mwamgongo, all in Tanzania, and Nyamuseni and Karonge/Kirasa in Burundi) were studied for geochronology, sedimentology, paleontology and geochemistry.

Although our principal goal was to document changes in the past few hundred years, one of our cores records a much longer period, showing a transition in the Mahale Mountains area from forest to grasslands between ~100-1300AD and a reversal of this trend subsequently, and correlated changes in lake ecology. This pattern of grassland expansion is observed elsewhere in Africa and is probably indicative of regionally drier conditions. It illustrates the potential for climatically induced change to mimic anthropogenic changes in watersheds, although there are also some significant differences between how such events are recorded in the sediments.

There is evidence in many of our cores for a change in vegetative cover manifest in upcore increases in tree pollen and fern spores at the expense of grass pollen over the past few centuries. We interpret this surprising outcome as the result of conversion of low elevation vegetation from mixed grassland/woodland conditions (in which the tree species are poor pollen producers) to subsistence agricultural land use, where the dominant crops (casava, bananas, coffee, legumes) also produce little pollen. The ongoing pollen rain during such a conversion increasingly reflects the residual high elevation forest and fern lands, which produce pollen and spores that are transported over long distances, primarily by wind.

Increased sedimentation rates at several of our study sites and correlated changes in the bulk composition and stable isotopic signature of sediments occurs simultaneously with these palynological changes and is most likely a result of increased hydrologic discharge and erosion rates on a progressively deforested landscape. These changes are evidenced in the northern parts of the lake prior to the 20th century, although a major acceleration of change dates to 1961 or thereabouts. That year is notable as one of exceptional rainfall and high lake levels throughout East and Central Africa, suggesting that although anthropogenic activities may be ultimately responsible for much of the change in watershed cover and erosion, increasing the discharge of those sediments to Lake Tanganyika may require a climatic "trigger". Small, disturbed watersheds or those with

steep underwater slopes show much less evidence of such effects than do large watersheds discharging onto more gentle lake floors.

Invertebrate communities (especially ostracode crustaceans) and their fossil record in Lake Tanganyika have responded to these watershed changes in complex ways. Under regimes where disturbance is very high and total sediment input is increasing, diversity is invariably low, and communities are dominated by species tolerant of heavy sediment loading. Again this is not strictly a 20th century phenomenon, particularly along the Burundi coastline, although the mid 20th century changes in accelerating watershed change are mirrored in some cores by correlative declines in diversity. Conversely, where or when disturbance levels are low, diversity is high and dominance is low. However at intermediate levels of disturbance the response is more complex and suggests thresholds of response. For benthic detritivores dependent on particulate organic matter input, modest increases in sediment input do not translate into declines in diversity or productivity (and may actually do the reverse). The ecological interpretation of fossils from Lake Tanganyika is complicated by a strong taphonomic overprint of differential transport of lightweight fossils (especially juvenile ostracodes, sponge spicules and charcoal) from the nearshore environment to the offshore settings where our cores were collected. However this taphonomic overprint need not be considered strictly a source of information loss. Potentially we will be able to turn these linkages between fossil accumulation and transport to our advantage, as they may provide important clues to increasing hydrologic discharge from deforested landscapes, where soil water storage is significantly reduced.

Our results suggest that the susceptibility of coastal (littoral, sublittoral and profundal) ecosystems of Lake Tanganyika to direct sedimentation impacts varies, depending on the nature of the hinterland watershed and underwater slope conditions. Larger watersheds, particularly those discharging onto relatively gently-sloping lake floors, such as we have studied in northern Burundi, are at greatest risk, and have probably been subject to high sedimentation rates even under conditions of relatively low overall watershed disturbance. This suggests that particular attention should be paid to large but currently undisturbed watersheds of this type further south in the lake, such as those discharging into the southern bays of Zambia or Tanzania, or the shallow platforms north and south of the Mahale Mountains. Conversely, steeply sloping lake bottoms, particularly those adjacent to small watersheds, are probably at lower risk of severe ecosystem damage from deforestation.

Future work should concentrate on obtaining detailed sedimentation rate information across one or two target deltas, to allow for meaningful modelling efforts to link lake sedimentation rate and hydrologic sediment flux data sets. Geochemical tracer studies may be useful in differentiating sediment sources, of particular concern for management recommendations in regions adjacent to the major river systems such as the Ruzizi. Botanical surveys and surficial pollen samples in the target watersheds are required to fully interpret the palynological data we have acquired. Similarly, gradient analyses of sediments and benthic invertebrate distributions across the target deltas will greatly clarify the extent to which the accumulation of these indicators reflects original distribution or transport.

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Chapter 1. Introduction

1.1 Need for Analysis

The paleolimnological component of the Lake Tanganyika Biodiversity Project was established to understand the history and timing of disturbances caused by watershed deforestation and the causal linkages between excess sedimentation and ecosystem change in Lake Tanganyika. Paleolimnology, the study of historical changes in lakes through an investigation of lake sediments, is a powerful approach for investigating ecosystem dynamics and anthropogenic impacts on lakes, particularly for time intervals or areas where instrumental or field observational data is lacking. These criteria are met in Lake Tanganyika and its watershed, where only limited historical data are available to assess the timing of human impacts to lake watersheds and their relationship to ecological changes in the lake. Most ecological investigations of sedimentation impacts on the lake to date have been of short duration and of limited regional scope. This impedes our ability to draw conclusions about the probable causes of observed differences in ecosystems between regions of the lake that are highly disturbed by human activities today, versus those showing lesser or no signs of watershed disturbance, since no chronologies linking the putative causes and effects can be obtained from such data.

The Paleolimnology Laboratory at the Department of Geosciences, University of Arizona was recruited to conduct a suite of analyses including dating sediment cores using radiometric techniques discussed below to determine changes in sediment accumulation rates, the analysis of the hard parts of organisms (ostracodes, mollusks, fish and sponges) by means of micropaleontological and paleoecological techniques and the study of geochemical tracers and sediments deposited in the study areas over the past several hundred years.

1.2 Purpose And General Approach Of The Study

The purpose of this study was to identify the timing and magnitude of ecological and environmental changes along the eastern shore of Lake Tanganyika over the past several hundred years. The conceptual approach we have taken is to compare the historical records of delta environments offshore from watersheds representing a spectrum of modern disturbance levels, from highly disturbed watersheds to lightly or undisturbed areas. Our original goal was to pair deltas of similar watershed size in such a way as to provide records from watersheds that differed primarily in their degree of disturbance, keeping other variables that are known to affect sediment discharge, such as slope, and bedrock composition constant. We examined six deltas on the east coast of Lake Tanganyika as representatives of highly to slightly disturbed drainages.

In any paleolimnological analysis it is important to bear in mind that a variety of environmental processes can cause changes in the variables we seek to interpret, of which human disturbance of the landscape is but one. In addition, direct climatic change (affecting vegetational cover), hydroclimatic changes involving changes in the depth of wind-driven mixing and productivity, and the autocyclic processes that generate changes in deltaic sedimentation patterns over time, are all known or suspected to have varied at the core sites over the past millennium, and all will have conspired to generate the record that we seek to interpret.

1.3 Review Of Previous Work

In the late 1980s and early 1990s, several studies by our University of Arizona research group identified probable linkages between ongoing watershed deforestation within Lake Tanganyika catchments and ecological changes in the lake's nearshore communities (Cohen et al., 1993, 1995). This work was stimulated by reports of accelerated landscape degradation in the Burundian catchments of the lake from agronomic investigations (e.g. Bizimana and Douchafour, 1991). Declining species richness and changing trophic structure were two types of change observed in fish, ostracode and diatom communities that were suggested to have resulted from sediment inundation, declining light availability and habitat simplification Alin et al. (in press) have provided additional support for this hypothesis based on diver and Remotely Operated Vehicle (ROV) transects of molluscs, fish and ostracodes at several sites in the northern portion of the lake. More recently, O'Reilly (1998) conducted benthic primary productivity experiments using the clear/dark chamber method and *in situ* measurements of key environmental variables, and found that net productivity increases in highly disturbed areas, but oxygen concentration and light penetration decrease.

Collectively these studies strongly suggest that human impacts related to watershed deforestation are affecting nearshore lake ecosystems in Lake Tanganyika. However, all of these investigations were of short duration and could not pinpoint the timing of ecological changes required to provide verification of the hypothesis. This shortcoming highlighted the need for a paleolimnological approach to studying this problem, since instrumentation and visual data did not exist to study this question over the time interval in question (the last century or so). Although numerous expeditions had investigated the paleoenvironmental history of the Lake Tanganyika region through coring prior to this work (e.g. Livingstone, 1965; Haberyan and Hecky, 1987; Gasse *et al.*, 1989; Vincens, 1989, 1991, 1993), these studies have generally been of insufficient temporal resolution to address questions about the timing of anthropogenic impacts over the past few centuries. Furthermore, earlier coring efforts have largely been directed at deep water, distal targets, which provide clearly interpretable stratigraphies, but which are distant from terrestrial inputs (thus obscuring those signals) and lack benthic invertebrate fossils. High resolution coring studies were first undertaken by the University of Arizona group to try and rectify this problem. Wells et al (in press) produced the first data documenting a historic (20th century) increase in sedimentation rates in the northern portion of Lake Tanganyika (Burundi coastline, near the Karonge/Kirasa river deltas), in an area with extremely low benthic biodiversity today. However a direct relationship between increasing sedimentation rates and declining diversity could not be established in that study. Some subsequent work showed that although the northern Burundi coastline has much lower benthic biodiversity today than do similar areas further south, that difference may have already been established as much as 1000 years ago or more (Cohen, in press). If sedimentation rate differences were responsible for the differences seen in diversity between northerly and southerly sites, then the watershed factors responsible for those differences must at least in part predate 20th century human population increases.

The coring and paleolimnological study described here was undertaken to provide a more comprehensive analysis of ecosystem change for a variety of watersheds along the Lake Tanganyika coastline. It also represents a major improvement on earlier paleolimnological studies in the quality of geochronology and the fact that the cores described here were expressly collected with the intent of analyzing changes over the decadal time scale and at the watershed spatial scale, something which was not the case with the earlier core analyses.

Chapter 2. Methods

A research cruise, consisting of three cruise legs, was conducted between 6-28 January, 1998 in Tanzania and Burundi to collect the samples and data analyzed in this study. During the cruise we collected bathymetric data, sediment cores and water samples from eleven deltas along the eastern coast of the lake, to investigate the long term changes in sedimentation rates associated with watershed deforestation and its impact on the ecology of Lake Tanganyika. Following this cruise, cores and other samples were sent back to Tucson, Arizona for detailed analysis. This work was completed between April, 1998-June, 1999.

2.1 Personnel

2.1.1 Field Personnel

Cruise Team Members – Leg 1 (6-16 Jan., 1998)
Dr. Andrew Cohen-University of Arizona-Project Leader and Chief Scientist
Dr. Manuel Palacios Fest-University of Arizona- Paleontologist
Mr. Jeffrey Houser-University of Wisconsin-Limnologist
Mr. James McGill-Embangweni Hospital-Coring Engineer
Ms. Emma Msaky-Tanzania Petroleum Development Corporation-Tanzanian Trainee
Ms. Catherine O'Reilly-University of Arizona-Limnologist
Dr. Graeme Patterson-NRI-Sedimentation Special Study Team Leader
Robert Sinyinza-Zambia Dept. of Fisheries-Zambian Trainee
Dr. Peter Swarzenski-U.S. Geological Survey, Geochemist
Mutanga Syampila-Zambia Dept. of Fisheries-Zambian Trainee
Dr. Dirk Verschuren-University of Ghent-Paleolimnologist

Leg 2 (19-24 Jan., 1998)
Dr. Andrew Cohen-University of Arizona-Project Leader and Chief Scientist
Dr. Manuel Palacios Fest-University of Arizona- Paleontologist
Dr. David Dettman-University of Arizona-Geochemist
Mr. Jeffrey Houser-University of Wisconsin-Limnologist
Dr. Kiram Lezzar-Univ. of West Brittany-Paleolimnologist
Mr. James McGill-Embangweni Hospital-Coring Engineer
Ms. Catherine O'Reilly-University of Arizona-Limnologist
Robert Sinyinza-Zambia Dept. of Fisheries-Zambian Trainee
Mutanga Syampila-Zambia Dept. of Fisheries-Zambian Trainee

Leg 3 (24-28 Jan, 1998)
Dr. Manuel Palacios Fest-University of Arizona- Paleontologist and Chief Scientist for Leg 3
Dr. Gaspard Bikwemu-University of Burundi-Palynologist
Dr. David Dettman-University of Arizona-Geochemist
Mr. Jeffrey Houser-University of Wisconsin-Limnologist
Mr. Bombi Kakagozo- CRH/Uvira, Zaire-Limnologist
Dr. Kiram Lezzar-Univ. of West Brittany-Paleolimnologist

Dr. Louis Nahimana-Univ. of Burundi-Sedimentologist
Dr. Gerard Ntungumburanye-IGEBU-Burundi-Geologist
Ms. Catherine O'Reilly-University of Arizona-Limnologist
Mr. Tharcisse Songori-Direction Gen. Geologie et Mines (Burundi)-Geologist
Dr. Kelly West-LTBP-Scientific Coordinator

2.1.2 Laboratory Personnel

Dr. Andrew Cohen-University of Arizona-Project Leader and Chief Scientist
Dr. Manuel Palacios Fest-University of Arizona- Paleontologist and Lab Research Coordinator
Dr. David Dettman-University of Arizona-Geochemist
Dr. Brent McKee-Tulane University-Supervisor of ^{210}Pb studies
Ms. Emma Msaky-Tanzania Petroleum Development Corporation-Palynologist (visiting scientist at the University of Arizona and Duke University for the duration of the project)
Ms. Heather Heuser-University of Arizona-Ostracode Analyst
Ms. Giana Gelsey-University of Arizona-Sedimentology Analyst
Mr. Brandon Tanner-University of Arizona-Laboratory Technician
In addition, Drs. Owen Davis (University of Arizona) and Daniel Livingstone (Duke University) provided supervision and training of Ms. Msaky in aspects of the project related to pollen analysis.

2.2 Study Localities And Field Work

2.2.1 Study Locality Selection

Data collection and sampling for this research cruise was organized around a strategy of collecting information about sedimentation impacts and rates around a variety of sized river deltas. To select appropriate study localities, an array of highly disturbed, moderately disturbed and relatively undisturbed drainage basins were grouped on the basis of similarities in drainage basin area, and to the extent possible, geomorphology and bedrock geology (Table 2.1). Study localities incorporating two drainages are those where the two rivers discharge in close proximity along the lakeshore and where the deltas of those rivers merge offshore. In such cases it is unlikely that deposits of the two systems could be differentiated without much more extensive work. Therefore those localities can be treated as single "deltas" for the purposes of this study. The original cruise plan called for a study of the Mitumba Stream Delta as the example of an undisturbed, very small drainage. This drainage basin is directly adjacent to, and approximately the same size (5.5km^2) as the Mwamgongo disturbed drainage. However bathymetric surveys and extensive coring attempts at this locality demonstrated that this site was too steep to allow for the successful operation of either the multicorer or gravity corer. The Luiche River Delta south of Kigoma was also surveyed, but the analysis of core material from that river delta was not possible under the terms of the present contract. An additional vibracore, LT-97-14V, collected by an earlier UA/U Miami GEF cruise in 1997 was analyzed as part of the current study for ^{210}Pb only. All site and sample information (including samples and cores collected for this study but not yet analyzed) is summarized in Appendix 1.

Table 2.1. Lake Tanganyika Deltas studied in this project.

Drainage Size Category	**River Name**	**Drainage Basin Area**	**Disturbance**			**Geologic Setting**
			Low	**Medium**	**High**	
Medium	Kabesi (Tanzania)	120 km^2		X		Precambrian metasediments on escarpment margin
Small	Lubulungu (Tanzania)	50 km^2	X			Precambrian metasediments on escarpment margin
Very Small	Mwamgongo (Tanzania)	8.5 km^2			X	Precambrian metasediments on escarpment margin
Very Small	Nyasanga/ Kahama (Gombe Area, Tanzania)	<2 km^2	X			Precambrian metasediments on escarpment margin
Small	Nyamuseni (Gitaza Area, Burundi)	30 km^2			X	Precambrian metasediments on escarpment margin
Medium	Karonge / Kirasa (Gitaza Area, Burundi)	42 km^2 / 120 km^2			X	Precambrian metasediments on escarpment margin

2.2.2 Bathymetric Surveys

Prior to coring, detailed bathymetric surveys were conducted at all study localities. Mapping was conducted using a combination of ship's echosounder and nondifferential GPS data. Generally these surveys were performed on a half-kilometer spacing grid, with depth and location data collected every 0.05 or 0.02 nautical miles along a transect line. Crude bathymetric maps were constructed by hand in the field to identify promising coring sites (i.e. sites which were both relatively flat and at an appropriate range of depths and distances from the river mouth). Detailed bathymetric maps were produced with Surfer for Windows software, using approximately 2,000 grid points per map. Surfer gridding was done using the krigging method, with a linear variogram model. Bathymetric grids were overlain onto shoreline maps from the relevant 1:50,000 topographic sheets for Burundi and Tanzania. All Tanzanian maps (Kalinzi sheet 92/1; Mgambo Sheet 131/4 and Buhingu Sheet 150/2) are Transverse Mercator projections. The single Burundi map (Gakara Sheet SA-35-XXIV-3b) is a Gauss Projection using Clarke's 1880 Ellipsoid. An original bathymetric data set (Appendix 4-disk version only) is included in the event that the TANGIS team wishes to regrid this data set using its own parameters.

2.2.3 Coring Operations

Once an adequate amount of bathymetric data had been collected for a locality to reconstruct the general geomorphology of its delta, coring operations could begin. Most coring work in this survey was undertaken using the LTBP's Hedrick-Marrs Multicorer. Under optimal conditions this device will collect four cores up to 57cm in length, each with a 10cm inner diameter. The cores are arrayed in a square grid that separates the center of each core from its neighbors by about 30cm. This arrangement allows the investigator to sample the same stratigraphic horizon from multiple core barrels (the device does not use a separate core barrel and liner). This coring device functioned extremely well, despite the frequently suboptimal coring conditions (high slope angle and coarse sediments) and almost every successful cast produced cores that had undisturbed tops (frequently, still living snails, copepods and ostracodes could be observed trapped in the surface waters of the core). Because the r/v *Tanganyika Explorer* is not optimized for geologic sampling (there is no functional boom or A-frame and the winches are oriented at an angle with respect to the stern of the ship) deploying and retrieving the corer over the rail proved somewhat unwieldy, and an effort was made to tie off the corer to the ship's rail when moving between closely adjacent core sites, or between coring attempts. It is recommended that LTBP rectify this problem prior to any future coring work by installing the necessary cabling and winch adapters to make the r/v *Tanganyika Explorer*'s boom functional, or alternatively to install a stern mounted A-frame that can hoist the multicorer and other coring devices over the rail more easily and safely.

Between 0 and 7 multicores were collected from each delta locality (Table 2.2). At several deltas very few or no multicores were collected because slopes were too steep across the entire delta front to allow the multicorer to deploy properly. At these sites gravity cores were taken to supplement the poor multicore recovery. An attempt was made to collect cores across a range of depth conditions and distance from river mouth, since the optimal conditions for geochronology and determination of sediment accumulation rates (extremely fine grained sediment, no bioturbation) do not occur in the same samples as those which are optimal for benthic faunal signals of sedimentation disturbance. Analyzed cores in this study necessarily had to compromise between the above factors, but ultimately we decided that it was critical to study sites within the oxic layer (based on modern oxygen penetration depths) in order to obtain a meaningful lake faunal ecology signal.

Multicores were extruded immediately upon retrieval in 1cm increments. Generally two of the four retrieved multicores were cut up, one being reserved for geochronological work (primarily ^{210}Pb and AMS ^{14}C) and a second for paleobiological, stable isotope and sedimentological studies. Areas with low multicore recovery were characterized by steep slopes (>30%), where the multicorer tumbled and did not deploy properly. At recovery, visual inspection allowed us to determine the two most appropriate cores to be processed for geochronological work (^{210}Pb and ^{14}C) and micropaleontological, sedimentological and stable isotope analysis. Cores used for micropaleontological and sedimentologic study are labelled with an "M" suffix, whereas geochronology cores are labelled "R", but it is important to bear in mind that in all cases the two cores are from identical multicore casts (i.e., they are separated from each other by only ~30cm, and sample the same stratigraphy. Cores were extruded at 1cm intervals, with the entire interval being retained (double bagged) for sampling purposes. Normally cores were logged for lithostratigraphy during extrusion, although this step was accidentally skipped during the sample extrusion of core LT-98-18.

In addition to multicoring operations, a number of gravity cores were taken for archival purposes. For this work we used LTBP's Duncan and Assoc. gravity corer, which takes a 6.8cm I.D. core, up to 2m in length. At most deltas at least one gravity core was collected at an optimal prior multicoring site, which will allow us to examine the physical stratigraphy of a larger interval of strata for each delta.

A small, hand operated dive corer was brought on board and used at the Nyasanga/Kahama site after ship-deployed corers failed to work on as many sites as we desired to collect. However sediments were sandy at diveable depths (approximately 0-30m) at these deltas and so core recovery with the hand corer was poor.

All core samples and intact cores were shipped to the University of Arizona and Tulane University for paleobiological, sedimentological, geochemical and geochronological analysis following the cruise. Core samples have been maintained continuously at 4 degrees C. in the Laboratory of Paleolimnology's (University of Arizona) core locker.

2.3 Geochronology

2.3.1 ^{210}Pb Analysis

^{210}Pb is an unstable byproduct of a long series of radiogenic decay processes originating from the decay of the long lived radioisotope ^{238}U. Its immediate predecessors, ^{226}Ra (half life 1622 yr) and ^{222}Rn (3.8 days) accumulate from parent materials in soil Ra, which is then released into the atmosphere as Rn. When Rn decays to ^{210}Pb it is washed out of the atmosphere, combines with particulate matter and (in a lake environment) can quickly enter the sediment, because of its low solubility. The flux of Pb to lake sediment is influenced by both atmospheric input, residence time in catchment soils and water, settling rate of Pb and particle size to which it is bound and the extent to which sediment becomes secondarily redeposited. The short half life of ^{210}Pb (22.3 yrs), makes it ideal for addressing questions of sediment accumulation rate and human impacts on lakes in the recent past (100-200 yr. time frame). Downcore ^{210}Pb profiles are interpreted against a background level of lead derived from direct ^{226}Ra decay in the sediments (i.e. not brought in via the atmosphere and water column). This **supported** lead background is augmented by the **unsupported lead** component derived from the atmosphere, which normally increases upcore. The slope and intercept of these curves are then used to establish sediment accumulation rate and age data.

All ^{210}Pb analyses were conducted at Tulane University, in the ^{210}Pb laboratory of Dr. Brent McKee. The polonium method of analysis of Nittrouer et al. (1979) and McKee et al (1983) was used in this study. An advection-diffusion model (Guinasso and Schink, 1975) was used to extract sedimentation rate information from the down core distribution of radionuclides.

Because of difficulties in obtaining adequate yields using standard leaching methods, a stronger method had to be used on these samples. Dried and ground sediments (~ 1-2 g) were weighed out (exact weight recorded). Sediment was then transferred into a Teflon microwave digestion vessel (CEM model MRS-2000 microwave digestion system). Approximately 2 ml of double distilled water was added followed by a known volume of ^{209}Po yield tracer (calibrated with NIST standard SRM-432). Acid mixture was added (4 ml of HNO3, 4 ml of HCl , and 2 ml of HF) and the digestion vessel was sealed. A microwave apparatus was assembled and a two step digestion was used (30 min at 100 psi followed by 30 min at 80 psi). Samples were allowed to cool and were then transferred into a Teflon centrifuge tube, centrifuged at 2000 rpm for 15 min. The acid solution was decanted from any undissolved residue into a plating vessel. The pH was adjusted to 2.0 and electroplated onto a stainless steel planchet for 20 hours.

The high cost of obtaining ^{210}Pb spectra necessitated choosing a single core for analysis per delta. We recognize the danger of placing overly great confidence in sedimentation rate and rate change results from a single site in a highly dynamic deltaic system, but it was decided that, given limited resources, it was preferable to examine multiple deltas rather than multiple cores for fewer deltas in this initial study. ^{210}Pb data is expressed in sedimentation rates (mm/yr) and calendar years for event correlation.

Sediment accumulation rates, calculated from ^{210}Pb and, to a lesser extent, from ^{14}C data, allow us to present a number of the quantitative sedimentologic and paleontologic variables in terms of both abundances per gram and as a "flux term", here simply calculated as abundance gm^{-1} x sedimentation rate (mm yr^{-1}). In considering these flux calculations however, it is important to keep in mind that many of the sedimentation events that make up these records may be pulsed, with higher "rates" representing those places and times when more such pulses were occurring over the sampling intervals (years to decades). If this is the case (likely on deltas), then fluxes are less meaningful statistics, and in all cases their interpretation should be treated cautiously.

2.3.2 ^{14}C Accelerator Mass Spectrometry (AMS) dating

^{14}C, the radiogenic isotope of carbon, is produced in the atmosphere by the interaction of cosmic radiation with ^{14}N. Free carbon quickly oxidizes to CO_2 and is subsequently taken up by plants via photosynthesis. The half-life of ^{14}C (5730 yr-decay is to ^{14}N) makes it ideal for dating organic matter in late Quaternary lake sediments. Complications in the interpretation of ^{14}C age dates arise from variations in the flux of cosmic rays into the earth's atmosphere and the fact that reservoirs for "old" carbon (i.e. depleted through radiogenic decay of ^{14}C) are common features of sedimentary environments, particularly in lakes. Lake Tanganyika is known to leak old, radiogenically "dead" carbon from its hypolimnion, limiting the utility of the ^{14}C method to organic matter that is washed into the lake from terrestrial sources. Alternatively correction factors can be applied to in situ organic matter or carbonates from Lake Tanganyika to attempt to account for this reservoir effect (e.g. Cohen et al., 1997).

^{14}C AMS dating involves the direct counting of the relative proportions of ^{14}C, ^{13}C and ^{12}C in milligram-sized samples of organic matter. An excellent review of the methodology is given in Litherlund and Beukens (1995). For this study, AMS ^{14}C dating was used to accomplish two goals:

1) Provide direct age dates on older parts of cores. Most cores studied here are relatively young and considerable uncertainty exists in radiocarbon ages for the past few centuries..

2) Identify core tops as "modern" based on the presence of an "ultramodern" ^{14}C signature. Atmospheric nuclear testing greatly increased the amount of ^{14}C in the atmosphere, resulting in an easily detectable signal in organic matter of this age.

Dated materials consisted of terrestrial plant matter, to avoid the problems of carbon reservoir effects and reworking of older materials alluded to above. When possible delicate leaves were used, to minimize the likelihood of reworking.

All AMS dating was done at the Tandem Accelerator National AMS Laboratory at the University of Arizona. All ^{14}C dates are reported as both uncorrected radiocarbon years B.P. (relative to 1950, these are reported in the tables only), and as corrected calendrical dates (AD or BC, used in all graphics and sedimentation rate calculations). Deviations between ^{14}C "years" and calendar years result from both variability in the production rate of ^{14}C in the atmosphere, and, for the industrial era, releases of old, radiogenically "dead" carbon into the atmosphere in unprecedented quantities (producing apparent ages that are too old for the 1870s - 1950s). Calendrical corrections were made using the Radiocarbon Calibration Program Rev 3.0.3 (Stuiver and Remier, 1993), with the additional Southern Hemisphere correction of -40 ^{14}C yr subtracted prior to making the calendar year calculations. Where multiple age picks resulted from the program (most instances) a preferred date is given on the lithostratigraphic columns, followed by alternative dates. We gave preference first to dates which were concordant with the ^{210}Pb chronology, secondly to those which were not discordant in terms of age reversals, and thirdly to those which required the fewest assumptions about major changes in sedimentation rates in the lower parts of the cores. Unless otherwise indicated, all radiometric age dates were used to assign sample ages through linear interpolation, or extrapolation from the closest adjacent dated horizon when necessary.

Ultramodern (i.e. post-bomb) ^{14}C results can, in principle, be assigned age dates, based on the rise and subsequent decline in atmospheric ^{14}C that resulted from the history and time of cessation of atmospheric nuclear testing. We used the ^{14}C curves of Nydal (1983) and Levin (1985) to estimate ages for our post-bomb samples. Given the uncertainty of these interpretations (and requisite extrapolation for samples younger than 1983) we present these interpretations only in Table 3.2 (all other graphics give these ultramodern results as "post-bomb" only, without attempting to assign a more precise age).

2.4 Sedimentological Analyses

Once all samples arrived at the University of Arizona we selected the best cores for use in this study, based on a combination of likelihood of providing continuous records, quality and quantity of indicator materials and comparability of coring stations vis-a-vis their distance from shore and water depths. Three splits from each core were sampled at 3 cm intervals for loss on ignition, sedimentological (granulometric and micropaleontologic), and palynological analysis, which corresponds to the average maximum depth of bioturbation and mixing observed in x-rays of deltaic cores from Lake Tanganyika. A total of 107 samples for each analysis were prepared.

For this exploratory study, a simple set of informative and inexpensive indicators was chosen for study. Granulometric analysis (grain size) provides indications of significant changes in the nature of eroded materials within watershed and the strength of sediment delivery systems to the coring site. Because total carbonate content in most cores was low, the contribution of nonterrigenous sources of coarser-grained particles in these cores is probably negligible. Over longer time intervals than are recorded in these cores grain size also may be indicative of significant changes in lake level. Water content and bulk density were measured as indicators of sedimentation rates. Total carbonate content and total organic matter were measured as indicators of benthic secondary productivity and terrestrial/aquatic productivity or organic matter flux, respectively.

2.4.1 Granulometry

All sedimentologic splits were prepared for granulometric and micropaleontologic analysis using the USGS freeze-thaw technique (Forester, 1991), modified by Palacios-Fest (1994). Approximately 10-20gm wet weight were used for each sample. For granulometric analysis samples were wet-sieved in a set of three sieves of >1mm, >106µm and >63µm mesh sizes to obtain the coarse sand, medium sand and fine sand fractions. Water content, calculated during Loss On Ignition sample treatment, was used in conjunction with sieve results to determine total fine fraction (silt+ clay) content. Data were logged and are presented graphically using Freelance Graphics for Windows.

2.4.2 Loss on Ignition (Total Inorganic Carbon and Total Organic Carbon)

All samples for loss on ignition were prepared using the technique described in Bengtsson and Enell (1986). This involves stepwise heating and reweighing of samples to 105, 550 and 925 degrees C for the determination of water content, organic carbon and inorganic carbon respectively. Data were logged and presented graphically using Freelance for Windows.

2.4.3 Charcoal

Charred particles can be excellent indicators of fire activity. Ideally charcoal should be point counted on known volume slides to estimate a volumetric flux. In this preliminary study it was not feasible to do this and charcoal abundance was estimated only as numbers of charred particles per gram, without consideration of particle size distribution. Particles were counted on the >106µm sieve fraction only, where most of the volume was concentrated, as an indicator of total abundance. We calculated abundances both as number per gram and as a flux (# gm^{-1} *sediment accumulation rate (mm yr^{-1}).

2.5 Ostracode Analyses

Ostracodes are small, benthic crustaceans whose calcite carapaces (shells) are ubiquitous parts of lake sediment records. They are extremely useful tools for lacustrine paleoecological research, both because of the intrinsic relationships observed between many species and their habitats, and also because their carapaces contain geochemical signals that can also be used for paleoenvironmental reconstruction.

2.5.1 Ostracode Faunal Analysis Methods

Sample splits from chosen cores were analyzed for ostracodes at three cm intervals. Ostracodes were disaggregated and separated using the freeze-thaw method of Forester (1991) and then wet sieved, along with other paleontologic samples. Counts of 500 individuals were made from the >106µm sieve fraction. We calculated ostracode abundances as numbers per gram of dry weight sediment, and as fluxes normalized by sediment accumulation rate.

Routine micropaleontological analysis on all samples from the sedimentological splits was conducted using a low power stereoscopic microscope and all samples were subsequently stored on either micropaleontological slides or in plastic trays. Ostracodes were identified to the species level wherever possible. Species identification was based on reference collections kept at the Laboratory of Paleolimnology of the University of Arizona and publications (e.g., Rome, 1962, Martens, 1993, 1994, 1997; Park 1995). Many species of Tanganyikan ostracodes are endemic and are still undescribed. For these, informal monikers (species numbers) are used, following the collection numbering at the University of Arizona. In addition to species identification, the following taphonomic indicators of ostracode preservation were tabulated for each stratigraphic interval: % fragmented valves, % encrusted valves (typically by calcium carbonate overgrowths), % abraded valves, a redox index (proportions of blackened, clear or reddened valves) %

whole carapaces (ostracodes have two shells connected across a hinge, that collectively comprise the carapace and these can disarticulate after death), % adults, and right/left valve ratios. All of these taphonomic variables can potentially provide clues to reworking of samples or, in the case of % adult valves, maturation of and ecological stress on the population.

2.5.2 Statistical Methods For Analyzing Ostracodes

Two statistical indices of diversity and similarity were used in this study to compare faunal assemblages. Fisher- Diversity Index quantifies the variation in species diversity (a function of both total species richness and the "even-ness" of that distribution, and is

$$a = \frac{N(1-x)}{x}$$

expressed by equation (1):

$$\frac{S}{N} = [\frac{1-x}{x}][-\ln(1-x)]$$

where x is estimated by iterating the following term (equation 2):
where S is the number of species in the sample and N is the total number of specimens.

The Jaccard's Similarity Index is used to compare faunal similarity between pairs of

$$CCj = \frac{C}{S_1 + S_2 - C}$$

samples (in this case, stratigraphically adjacent samples) (equation 3):

where C is the number of species common to both samples and S_1 and S_2 is the total number of species on each sample. We used the Jaccard Index to identify overall faunal similarity through core sequences and times of rapid faunal overturn. In addition, correspondence and cluster analyses using XLSTAT were conducted on every core to establish species associations to be used as environmental indicators.

2.6 Palynology

The analysis of fossil pollen forms an extremely important part of many paleolimnological studies concerned with land use change, because it allows connections to be drawn between watershed processes (in terms of vegetation structure) and lake paleoecology. The analysis of fossil pollen from the cores described here was conducted under a separate contract from the one funding this study. However the work was done simultaneously, and in close collaboration with this study, and both data and major conclusions are reported here. Palynological investigations were performed by Ms. Emma Msaky (Tanzania Petroleum Development Corporation) under the supervision of Dr. Daniel Livingstone (Duke University) and processing work was done in the laboratory of

Dr. Owen Davis (University of Arizona).

Pollen samples were taken every 3cm from each core. A total of 106 $1cm^3$ samples were analyzed. Pollen was extracted using standard methods employed by the University of Arizona palynology lab. Volumetric sediment samples were added to water and detergent, washed and screened on a 180: mesh sieve. *Lycopodium* tablets were added as tracers and then the samples were progressively acidified with 10 % HCl and 36%HCl for carbonate removal and 48% HF for removal of silicates. The samples were then subject to acetolysis (acetic acid, acetic anhydride and sulfuric acid treatment), decanted and boiled in a KOH bath, prior to staining (safrinin "O"). Samples were then transferred to shell vials for storage prior to mounting and counting. Counts averaged 300 grains, and pollen data is presented as percentages based on these counts. Counting was done at 400X using an Olympus microscope and "Kounter" software.

Pollen identification was based on the ~35,000 pollen slide reference collections of D.A. Livingstone at Duke University. Unpublished keys in Livingstone's laboratory were used as guides to the reference collection. Most pollen was identified to genus. Habitat inferences were based on the *Flora of Tropical East Africa* (Pohil, ser. in multiple volumes), *Flora Zambesiaca* (Pope, ser. in multiple volumes) and *Flora of Tropical West Africa* (Hepper, 1963, 1968), in that order of preference. Additional habitat information was obtained from comparison of our results with floristic surveys of Gombe Stream National Park (Clutton-Brock and Gillett, 1979; Gereau *et al.*, in press). Data was plotted using *Tilia* software of Eric Grimm (Illinois State Museum).

2.7 Other Paleontological Analyses

In addition to ostracodes and pollen, other fossils that were routinely collected in 106: or coarser sieved samples were counted and tabulated. These include fish bones, molluscs fragments and sponge spicules.

Little work has been done to date to determine the paleoecological significance of total sponge, mollusc and fish bone counts in Lake Tanganyika, so this attempt should be viewed as exploratory in nature. Sponges are filter feeders known to be sensitive in stream ecosystems to high levels of turbidity. Several endemic species of both erect and encrusting sponges are known from Lake Tanganyika, although little is known of their ecology in detail.   In principle, the abundance of their siliceous spicules (skeletal elements) might reflect turbidity and ecological impact on benthic filter feeding communities. However we have no information on the taphonomic controls of transport and resuspension that may affect local abundances in sediment cores. Furthermore, sponges are extremely abundant on the undersurfaces of rocks today in northern Burundi, where sedimentation rates are high, suggesting that other factors, such as grazing intensity, may be more important than turbidity *per se* in regulating sponge density in Lake Tanganyika.

Tanganyikan molluscs also display high degrees of endemicity, although the range of trophic guilds occupied by these species is much wider than the sponges. Most gastropod species encountered as fossils in sub-wave base cores are detritus feeders, and all of the species encountered are likely to be derived from soft-bottomed habitats. Tanganyikan bivalves are filter feeders, but are comparatively rare in these cores. A total abundance of mollusc fragments, normalized for sediment accumulation rate (most are not preserved as whole shells) may then be indicative of secondary productivity in the detritus feeder food web. Again taphonomic constraints limit our ability to interpret these data, although prior investigations do provide some guidelines (Cohen, 1989)**.**

Disarticulated fish bones are common fossils in core materials from Lake Tanganyika. Currently a UA student (Giana Gelsey) is doing a preliminary study of the paleoecological significance of fish bone material, although the full results of that work were not available at the time of writing this report. Fish bones encountered in offshore samples such as our cores represent, are likely to sample the relatively simple pelagic fish community (2 species of clupeid "sardines", and four species of predatory *Lates*). Additionally, deep benthic cichlids may be represented in these samples, although they are likely to be impossible to key at the species level from disarticulated bone. One common observation we have made in many surface and core samples to date is an interesting inverse correlation between the abundance of fish and ostracode skeletal material, suggesting that factors that favor ostracode (detritus feeder) production may be inimical to fish bone accumulation. However, whether this represents a biological, taphonomic or mixed phenomenon is unknown.

Because of the time constraints placed on completing this project and (for fish and sponges) uncertainties in identifications, no attempt was made to identify these materials by species. However, the material has been retained and, for the molluscs at least, such identifications could be done easily in the future. All three groups are enumerated as both abundances per gram dry weight of sample, and normalized to sediment accumulation rate to provide values proportional to flux rates.

2.8 Stable Isotope Stratigraphy

Stable isotopic analyses of calcium carbonate minerals is a widely used tool in paleolimnology to detect changes in waterbody composition and residence time (e.g. Cohen *et al*., 1997). The ratios of the important stable isotopes of oxygen (^{16}O and ^{18}O) and carbon (^{12}C and ^{13}C) are frequently correlated with variations in climate and water input (in the case of oxygen) and behavior of the local carbon cycle and perhaps photosynthesis in the case of carbon.

For this study ostracode valves were used as the source of calcium carbonate for both C and O isotope analyses. Ostracodes seem to secrete their valves with a minor offset to isotopic equilibrium with lake water with respect to oxygen (Dettman et al., 1995a; Xia et al. 1997), and can be used to track the change in oxygen isotope composition of the local lake water. The interpretation of carbon isotope composition is more problematic, since ostracodes are benthic organisms, living near the sediment water interface, where many reactions involving uptake and release of carbon occur. Metabolic processes can also have a significant effect on the carbon isotope composition of ostracode shell and for this reason we focus only on the oxygen isotope ratio in this study.

We focused on one species of ostracode, *Romecytheridea* sp. 13, in this analysis. This species is predominantly a shallow water/near shore mud dweller and is most likely a good monitor of variation in the isotopic composition of water in the delta caused by changes in runoff into the lake.

Because the ostracodes in the study cores are juveniles and poorly calcified, it was necessary to lump 20 individuals into a single sample, to provide sufficient carbonate for analysis. Once the required number of valves were picked adhering sediment was removed with a fine (000) brush in 4X distilled water. Fossils were analyzed on a Finnigan MAT 251 mass spectrometer paired with a KIEL automated sample preparation device at the University of Michigan Stable Isotope Laboratory. Standard error of results is +/-0.08 per mil for $\delta^{18}O$ and +/- 0.06 per mil for $\delta^{13}C$, based on a replicate analysis of NBS-19, and Univ. of Michigan internal standards. All carbonate values are expressed relative to PDB, water $\delta^{18}O$ values are relative to SMOW.

Chapter 3. Results

3.1 Descriptions Of Study Watersheds

Study watersheds and core sites are described sequentially from south to north (Fig. 3.1). The geographic scope of this study (central Tanzania to northern Burundi) reflects the time available to complete the field work (approximately one month total cruise time) and the feasibility of operations from our support base (Kigoma, Tanzania). All study areas have similar patterns of rainfall seasonality (i.e. rains concentrated between October and April and very dry, windy conditions from June to early September), although considerable variation exists in total rainfall between sites and from year to year.

Table 3.1 List of study deltas and coring stations in this report.

Delta	Station #	Date/Time	Lat. (decimal)	Long. (decimal)	Water Depth (m)
Lubulungu	LT-98-2	1/7/98-1025	-6.1653	29.706	110
Lubulungu	LT-98-12	1/8/98-1158	-6.1655	29.71783	126
Kabesi	LT-98-18	1/10/98-1305	-5.976833	29.816667	75
Nyasanga/Kahama	LT-98-58	1/15/98-1015	-4.68833	29.61667	76
Mwamgongo	LT-98-37	1/13/98-1200	-4.62267	29.633167	95
Nyamuseni	LT-98-98A/M*	1/26/98-1305	-3.619333	29.340167	60
Karonge/Kirasa	LT-98-82	1/25/98-0756	-3.5835	29.325167	96
Malagarasi**	LT-97-14V	2/15/97	-5.1400	29.73283	73

* The A/M designations refer to two distinct barrels of the four-barreled multicorer. For many cores more than a single barrel was required for sampling purposes.

** The Malagarasi core LT-97-14V was only analyzed for Pb-210 for this study.

3.1.1 The Lubulungu River and Delta, Mahale Mountains National Park, Tanzania (Fig. 3.2)

This $50km^2$ watershed is located on the western side of the Mahale Peninsula that juts out into the lake about 120 kms south of Kigoma. The watershed lies entirely within the Mahale Mountains National Park, at elevations between lake level and ~2000m. Local climate is strongly influenced by orographic effects related to the Mahale Mountains. Rainfall at Kansyana, 4km north of the Lubulungu River Delta, averages 1870mm/yr, whereas at Bilenge, only 9km further north, but less directly adjacent to the Mahale Mtn front, rainfall averages 1400mm/yr (Bygott, 1992).

Bedrock lithology within the Lubulungu watershed comprises Paleoproterozoic (Ubendian) metasedimentary rocks (dominantly gneisses, with secondary amphibolites and schists), and in the upper portion of the watershed, some metabasites, intermediate granulites and quartzites (Schluter, 1997) . The physiography of the Lubulungu River Valley comprises a deeply incised valley with considerable relief and several areas of rapids (Fig. 3.2). The watershed itself is relatively small ($50km^2$). Major rift-related border fault structures and orthogonal joint systems traverse the western margin of the watershed and strongly influence the rectilinear pattern of tributaries feeding the Lubulungu. From map inspection parts of the upper portion of the adjacent watershed appear to have been involved in relatively recent episodes of stream piracy, reducing the Lubulungu drainage basin from a formerly larger size.

Vegetation cover within the watershed is stratified by elevation, consisting of relatively dense lowland forest up to about 1300m, then a mixture of bamboo bushland and montane forest (above 1800m) gradually dominated by the latter (*Podocarpus, Bersama, Macaranga* and *Croton*) (Bygott, 1992).

The Lubulungu River Delta forms a prominent fan-delta on land where the river discharges from its deep canyon front. Offshore the delta occupies a prominent ESE-trending topographic high, which, based on its size and sediment accumulation rate data discussed later, is probably fault bounded. This bench slopes gently into deeper water, merging with the surrounding border fault controlled slope break at about 150m water depth. Coring activities were concentrated on the bench and adjacent gently sloping areas to the north, to avoid problems with secondary resuspension on steep slopes.

The Mahale Mountains National Park, which completely encompasses the Lubulungu watershed appears to have been protected since the early 1960s but the National Park was not gazetted until 1980. The park has an area of 1,613 km^2, located between 6° and 6°30' S and 29°40' and 30°10' E. Human population density within the Lubulungu drainage is low (<5 people/km^2: team's observation, 1998) and there are no roads. The watershed's small size further limits sediment discharge.

3.1.2 The Kabesi River and Delta, Mahale Mountains, Tanzania (Fig. 3.3)

The Kabesi River Delta lies on the northern end of the Mahale Mountains Peninsula. The watershed is considerably larger (120 km^2) than the Lubulungu drainage basin. It drains much of the northeast flank of the Mahale Mtns, over part of its course lying adjacent to the Lubulungu watershed. The Kabesi drains the highest portions of the Mahale Mountains (up to about 2500m) and flows northwest towards the northern side of the Mahale Peninsula. The watershed straddles the current National Park boundary. Rainfall data are not available from the watershed but are probably comparable to the range of values observed near Lubulungu, with perhaps somewhat higher levels of precipitation than Kansyana at the highest elevations and somewhat lower values than Bilenge on the river's northern coastal plain.

The Kabesi River traverses similar bedrock geology to the Lubulungu, although the proportion of meta-igneous rocks (esp. metabasites) is higher in the Kabesi watershed. also like the Lubulungu, the river's morphology is strongly controlled by NNW-trending rift-related structures (themselves overprinted on the major Proterozoic structural grain of the region). In its upper reaches the Kabesi runs through a deep (~1000m) canyon, with most tributaries rising off the high Mahales to the southwest and entering the Kabesi at near 90 degree angles. The Kabesi exits this valley over its last 10km, traversing low hilly terrain, and, over its last 2-3km, a lowland delta.

Vegetation patterns of the Kabesi differ from the Lubulungu as a result of the greater range of relief and rainfall found in the basin. Lowland areas are partially cultivated (primarily bananas, casava and oil palm) and cleared by brush fire, particularly within the coastal plain, and locally irrigation works have partially diverted the modern river flow. Extensive miombo woodland (*Brachystegia*, *Isoberlinia* and *Julbernardia*) occupies the lowland foothills. Higher elevation areas are similar to those of the Lubulungu, but at the highest elevations (>2300m) forests give way to montane grasslands.

The Kabesi Delta forms a ~5km wide lobe of sediment, evident both above and below the lake. The delta is partitioned by two prominent (~N-S) sublacustrine canyons up to 30m deep, which increase in relief below 100m depth and probably serve as major distributary channels to focus sediment off the coastal Mahale Platform.

Although human population density is still low (10-20 people/km^2 -team's observation, 1998), fishing and localized agricultural activity, concentrated in the lowlands of the watershed, outside of the Mahale Mountains National Park boundary, contribute to modifications in the watershed environment.

3.13 The Nyasanga/Kahama Rivers And Delta-Gombe Region, Tanzania (Fig. 3.4)

The Nyasanga and Kahama river valleys lie entirely within the Gombe Stream National Park. Both are very small drainages, arising at the crest of the local rift escarpment. Because of their close proximity and our inability to differentiate their deltas bathymetrically, we treat them here as a single watershed entity. Rainfall, total relief and bedrock geology are similar to the Mwamgongo watershed, although the aerial extent of these watersheds is smaller (~2.5km^2) than Mwamgongo.

Vegetation within these watersheds consists of semi-deciduous woodland (*Combretum*, *Anisophyllea*, *Schrebera*, *Pterocarpus*), wetter canopy forests (*Albizia Newtonia* etc.) and riverine forest at lower elevations and dry (*Brachystegia* or *Uapaca* dominated) forest and open grasslands at higher elevations. Along the lower elevation stream channels relicts of cultivated lands (particularly mango and oil palm) occur. Higher elevation grasslands are burned on a near-annual basis, both within and outside of the national park, and the demarcation between woodlands and deforested grasslands is both sharp and (based on analysis of older aerial photographs taken in 1950s) relatively stable.

A bench of relatively gently sloping, coalesced fan delta fronts flanks the coastline through much of southern Gombe Stream Park. Consequently, individual "deltas" cannot be recognized based on our bathymetry. As with Mwamgongo this bench gives way to a very steeply sloping bottom about 0.5km offshore.

Because the Nyasanga/Kahama watersheds lie entirely within the Gombe Stream National Park their only permanent residents are nearby park personnel and their families (<5 people/km^2 in the Nyasanga/Kahama watersheds; Park's administrator pers. comm., 1998). Temporary fishing camps are also established along the fan deltas (Fig. 3.4).

3.1.4 The Mwamgongo River And Delta-Gombe Region, Tanzania (Fig. 3.4)

The Mwamgongo River occupies a small (8.5km^2) watershed at the northern edge of Gombe Stream National Park (the southern edge of the watershed approximates the northern park boundary), approximately 30 km north of Kigoma. The watershed runs approximately E-W, traversing the area from the upper (eastern) flank of the local rift escarpment (~1600m) down to Lake Tanganyika. Rainfall at both Mwamgongo and Nyasanga/Kahama is approximately 1600mm/yr, and possibly higher in the upper parts of the watershed.

Bedrock geology within the Mwamgongo watershed is dominated by Kibaran (middle Proterozoic) metasediments. The watershed occupies a small, steeply sloping valley draining the major rift boundary fault surface. A ~0.5km diameter fan delta has formed at the discharge point into Lake Tanganyika.

The Mwamgongo River watershed vegetation is dominated by cultivated areas (particularly casava on steep slopes and oil palm and bananas along valley bottoms) and disturbed (burned and grazed) grassland. Relict patches of miombo (*Brachystegia*) woodland occur in parts of the watershed, particularly at higher elevations.

Because the Mwamgongo River drains a major rift escarpment, the subaqueous development of the river's fan delta is very limited. A small, relatively flat bench extends for approximately 0.4km offshore, and almost all successful coring for this study area was accomplished here (including core LT-98-37, described in this report). West of this bench water depths increase rapidly, and the 1000m depth contour lies only about 1.5km offshore.

Human settlement patterns for the Mwamgongo watershed were broadly documented by our team through interviews with the local village elders and census keepers. Prior to the 1940s Mwamgongo was a small village, probably with about 1000 people. In 1943 the colonial government gazetted the Gombe Stream Reserve and relocated inhabitants north of 4°38'S by the Mwamgongo River (Bygott, 1992). The population of Mwamgongo village consequently increased greatly in the late 1940s. A second period of rapid population increase occurred in 1972, during the Tanzanian government "villagization scheme", when many individuals from small nearby villages were resettled in Mwamgongo. At present about 7,000 people live within the watershed (i.e. ~800 people/km^2). Extensive clearing of steep slopes, particularly within the lower parts of the watershed, are generating rapid soil erosion in the area.

3.1.5 The Nyamuseni River and Delta-Gitaza Region, Burundi (Fig. 3.5)

The Nyamuseni River drains a 30 km^2 watershed in northern Burundi, approximately 28km south of Bujumbura, near the town of Gitaza (Buyenzi). The river rises in the Burundi highlands, with maximum elevations in the watershed of about 2500m. Rainfall data are not available for this area, but are probably slightly higher than Bujumbura (~850mm/yr) for the lower elevations (based on the increased rainfall gradient towards southern Burundi, e.g. Nyanza Lac = 1080mm/yr), and much higher in the upper reaches of the watershed.

Bedrock geology within the Nyamuseni River watershed consists of Middle (?) Proterozoic metasediments (quartzites and amphibolites) and (particularly in the northern part of the watershed) Kibaran (mid-Proterozoic) granites and minor mafic intrusive rocks. The river rises within the rift and steeply traverses a series of ~N-S oriented rift-related normal faults in deeply incised canyons, but its course shows little obvious relationship to secondary rift structures.

Both the Nyamuseni and the Karonge/Kirasa discussed below have been almost completely deforested of primary woodland/forest cover, with land use primarily converted to agricultural purposes (monocultures of cassava cultivation on steep slopes and banana and oil palm cultivation in river bottoms or lowlands near the lake, with little additional ground cover). Many areas of steep slopes are covered by disturbance shrubs, herbaceous plants, ferns or grasses where croplands have been abandoned or slopes are too steep for planting and may be barren of vegetation in some areas. *Eucalyptus* has been planted extensively in monocultures in the upland regions since the early 1930s (experimental plantings began in the late 1920s, P. Ndabaneze and K. West, pers. comm., 1999), mostly for fuelwood.

The Nyamuseni River has built a steep-fronted fan delta into the lake, lobes of which can be traced for up to several kilometers offshore. Water depths into which this delta is building in this northern part of the lake are considerably shallower than in either the Gombe or Mahale regions.

The Nyamuseni watershed is heavily disturbed by human activity, including agriculture on steep, unterraced terrain, criss-crossed by numerous unregulated paths, which become important arroyo cuts after major rains. Unlike the previously discussed sites, the Nyamuseni watershed is traversed in its lower reach by a paved road (and several smaller, unsurfaced roads), the construction and maintenance of which generates large quantities of rip-rap, which has been discharged directly into the adjacent parts of Lake Tanganyika. Population density is high in this region (200-399 people/km^2: Alin et al., in press).

3.1.6 The Karonge/Kirasa Rivers and Delta-Gitaza Region, Burundi (Fig. 3.5)

The Karonge/Kirasa delta is located about 20km south of Bujumbura on the northern Burundian coast of Lake Tanganyika. The two rivers converge near the lakeshore to form a contiguous delta lobe. Collectively, they drain a considerably larger area than the Nyamuseni River alone (Karonge = 42km^2, Kirasa = 120km^2). Maximum elevations within the watershed are about 2100m, somewhat lower than the Nyamuseni. This fact, plus the more northerly location, suggests that average rainfall values within the watershed are probably slightly lower than for the Nyamuseni, although no precise data is available to us.

The bedrock geology of the Karonge/Kirasa watersheds is almost entirely Kibaran (middle Proterozoic granitic rocks), with minor gneissic rocks exposed only in the northern part of the Karonge watershed. Physiography is similar to the Nyamuseni, with deeply incised consequent drainages off the local rift escarpment that show little or no strong post-uplift structural control.

Upland vegetation is also similar to the Nyamuseni, although significant patches of montane forest vegetation still existed within the central upper river basin as of 1984 (date of most recent satellite photographs available to us), particularly along steep-sided river valleys in the upper Kirasa basin between ~2000-2200m . However the lowland area encompassed by the Karonge/Kirasa delta is much larger and consequently the extent of lowland cultivation (especially oil palm) is much more extensive.

The Karonge/Kirasa subaerial delta forms a prominent geomorphic feature, and marks the southern edge of the Burundian coastal plain. Subaqueously, no deltaic lobe is evident, and bathymetric contours expand continuously towards the north, suggesting a major input of sediment from the north (presumably the Ruzizi River system extending as far south as this area). The idea that Ruzizi River sediments significantly inundate the Burundi coastal plain as far south as the Karonge/Kirasa area receives further support from fossil pollen analyses (discussed below). As a result of this unexpected finding the UA group has begun a preliminary study to develop geochemical tracers (specifically Sm/Nd ratios, which we believe will discriminate between "local" vs. Ruzizi inputs), which eventually may allow us to quantify the relative fluxes of sediments from the local vs. the Ruzizi systems.

Local structural control also undoubtedly plays a role in the change in bottom morphology, as the major rift-related border fault in this area extends inland to the north of these rivers. Water depths and bottom morphologies in front of the Karonge/Kirasa delta were the shallowest and most gently sloping of any encountered in our study areas.

Human settlement and disturbance patterns are comparable to those observed in the Nyamuseni watershed, with the exception that the proportion of lowland population to total density is probably higher, because of the considerably larger coastal plain. Rip-rap and construction input from major road works to the lake is probably lower for the Karonge/Kirasa system given the greater distance from the surfaced road to the shoreline in this area.

3.2 Core Site Descriptions And Physical Stratigraphy Of Studied Cores

Brief descriptions of each representative core (the one or two cores chosen for analysis per delta) are given below. Details about the collection localities for the numerous other cores collected by this project but not yet examined, are given in Appendix 1.

Lubulungu Cores.

Cores LT-98-2M and LT-98-12M were collected from the west-central part of the Lubulungu River Delta. Core LT-98-2M was collected in 110 m of water depth in the central plain of the delta, about 1.5km offshore and west of the Mahale Mountains National Park, Tanzania (Figs. 3.2 and 3.6). Swimming copepods and clear water at the core/water interface indicate that the sediment surface was undisturbed by collection. The core consists of 49 cm of alternate massive sandy clay and clay, either with shell fragments or plant remains, or occasionally both. A notable and abrupt fining of sediments occurs above 35cm.

Core LT-98-12M was collected in 126m water depth, about 500 m northeast of core LT-98-2M (1.2km from shore), on a narrower and deeper slope of the delta front (Figs 3.2 and 3.7). It consists of 40 cm of alternating massive sandy clay either with mollusk fragments or plant debris and wood fragments, occasionally both. In general, sediments coarsen upwards, notably so in the upper 10cm.

Kabesi Core.

Core LT-98-18 was collected about 1.5km offshore from of the Kabesi River mouth, in 75m water depth (Fig. 3.3 and Fig. 3.8). The core top sampled a live *Paramelania iridescens* in living position, indicating perfect recovery of the sediment-water interface and oxic conditions at the core site. The core consists of 42cm of brown massive muds, which show a noticeable coarsening upwards pattern in the uppermost ~12cm of the core. This core was accidentally sampled prior to the preparation of a detailed field description, hence the lithostratigraphic diagram is not as detailed as in other cores.

Nyasanga/Kahama Core.

Core LT-98-58M was collected in 76m of water depth, about 300m offshore from Gombe Stream National Park and the Nyasanga/Kahama coastal sand belt. The precise coring locality formed a small topographic bench on an otherwise steep slope allowing for sediment accumulation. It consists of 39 cm of brownish to dark gray clays (Figs. 3.4 and 3.9). Sediments alternate between laminated silty clay and massive clay with carbonate layers and shell fragments, and display a slight coarsening upwards above ~16cm. The sediment/water interface consists of flocculent clay.

Mwamgongo Core.

Core LT-98-37M was collected in 95m water depth about 300m offshore from the Mwamgongo River, north of the Gombe Stream National Park, Tanzania (Figs. 3.4 and 3.10). Like the Nyasanga/Kahama site, this coring location was a flat bench on an otherwise steep slope. The overall core condition and core top water/sediment interface preservation were excellent. The sediment/water interface consists of flocculent clay with abundant live copepods, ostracodes and snails. The core consists of 45 cm of brownish clays. Alternating massive silty clay and dark sandy organic clay occur throughout, along with carbonates, and the core displays a slight fining upwards. A striking transition to reddish clays near the core top was observed in this core and the other cores we collected from the Mwamgongo Delta.

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Nyamuseni Core.

Core LT-98-98M was collected in 61m water depth, about 100m north of the Nyamuseni River discharge point and approximately 200m offshore (Figs. 3.5 and 3.11). The core site is on the proximal part of an elongate spur or ridge extending off the delta, which, based on its shape, may be a small structural high. The core and core top were in excellent condition at recovery. The core consists of 37 cm of alternating brown sandy clay and micaceous clay, with or without plant debris. The sediment/water interface consists of clayey sand.

Karonge/Kirasa Core.

Core LT-98-82M was collected in 96m water depth, 1.2km due west of the Karonge and Kirasa delta (Figs. 3.5 and 3.12). The core site is a broad, gently dipping slope. The core and core top were both in excellent condition at recovery. The core consists of 46 cm of alternating dark gray and gray, laminated or massive clays. The sediment/water interface consists of flocculent organic clay.

3.3 Geochronology

3.3.1 ^{210}Pb Dating and sediment accumulation rates

^{210}Pb profiles for six cores are presented in Figures 3.13 through 3.18. A full raw data set of ^{210}Pb results is provided in Appendix 2. Both cores from the Lubulungu area, LT-98-2 and LT-98-12 were determined by radiocarbon measurements (discussed below) to be too old to obtain informative ^{210}Pb geochronologies. Because of our inability to obtain meaningful ^{210}Pb data for the Lubulungu area we have substituted a core from a 1997 UA/U Miami/LTBP cruise, obtained from the Malagarasi Delta region. This core (LT-97-14) provides a useful point of comparison for understanding sedimentation rate changes in the region. The Malagarasi core, obtained in 73.1m water depth, 8.5km due west from the northern distributary channel mouth of the Malagarasi River, and is currently under study by Simone Alin (University of Arizona Ph.D. student). Additionally, a number of cores with good ^{210}Pb geochronologies collected from the study area in the context of other projects by the UA team (1997 and earlier cruises) will be referenced because of their bearing on the sedimentation rate questions addressed here.

Unsupported ^{210}Pb activities are high to very high in most of the cores, allowing us to obtain comparatively long geochronologies (up to ~10 half-lives in some cases). Down-core unsupported ^{210}Pb varies in very systematic ways in almost all profiles, making them readily interpretable. One core, LT-98-98 (Nyamuseni) shows an abrupt increase in unsupported ^{210}Pb activity at ~30cm, that cannot be readily interpreted with an age model, but nevertheless has interpretable implications for changes in sedimentation rate.

The five cores fall into two clusters. Cores LT-98-18 (Kabesi), LT-98-98 (Nyamuseni), LT-98-82 (Karonge/Kirasa), and LT-97-14 (Malagarasi) show abrupt and dramatic upcore changes (in some cases, multiple times) in sediment accumulation rate. These rates are independent of water content, which, below about 1.5-2cm, is relatively invariant through the core lengths analyzed. A second set of cores, LT-98-58 (Nyasanga/Kahama) and LT-98-37 (Mwamgongo), show no such changes, with unsupported ^{210}Pb activity increasing exponentially upcore, consistent with relatively constant sediment accumulation rates throughout the ^{210}Pb-dated interval. LT-98-37 does however show an increase in rate from the ^{14}C dated portion of the core (discussed in the next section) and the ^{210}Pb-dated interval, during the early to mid 19th century. Sediment accumulation rates for the "constant rate" sites and pre-increase rates for the remaining sites are remarkably similar, considering the large differences in deltas, rivers feeding them and slope/tectonic setting. All fall into the 1.0-1.5mm/yr range. Similar rates have been obtained in other cores from the region, although the range of values (0.7-2.3mm/yr) is somewhat greater. In contrast, rates for the upper portions of cores that show increases vary widely, from 3.5-9.0mm/yr. Where these changes can be dated (cores 18, 82 and 14) they show a striking correspondence of dramatic increases about 1961. As mentioned earlier, precise ^{210}Pb ages and rates cannot be inferred from LT-98-98, but the pattern of change upcore and the constancy in the upper 30cm suggests rates of perhaps 10mm yr^{-1} or more. The vertical profile exhibited by this section of the core can be interpreted to imply that sedimentation rates are increasing by a rate approximating a doubling per half life (22.3 years). This interpretation is consistent with the ultramodern ^{14}C dates obtained throughout this core (see Figure 3.11) and discussed below, which argue for average rates over the past 40 years of about 10mm yr^{-1}. Vertical uniformity in an unsupported ^{210}Pb profile can also be interpreted to represent vertical mixing or homogenization of the upper sediments, particularly through bioturbation. However, given the normal depth of bioturbation in Lake Tanganyika sediments accumulating at these depths (1-3cm) and the fact that much of this interval is laminated or microlaminated, we find this explanation implausible, and conclude that the LT-98-98 profile results from an extremely rapid increase in the rate of sediment accumulation. Minor reversals in upcore increasing profiles (e.g. at ~22cm in LT-98-82) probably represent brief hiatuses or reworking events, both common features of deltaic sedimentation.

Cores displaying large upcore increases in sediment accumulation rate are all from deltas of medium to very large, disturbed watersheds. In contrast, the two cores displaying no upcore change were both collected offshore from very small drainages, representing very different disturbance regimes. Other ^{210}Pb-dated cores from the region conform to this generalization, in that areas offshore from small drainages show either no change over time in sedimentation rates, or in some cases actually show declines, either in the late 19th or mid 20th century.

Figure 3.19 shows the geographic and temporal pattern of change in sediment accumulation rates based on ^{210}Pb results through the study area. This map incorporates our earlier results, as well as those derived from the 1998 cruise. The 1961 inflection in sediment accumulation rates is particularly striking, as it is observed in three very widely separated and geomorphically different regions.

3.3.2 AMS ^{14}C Dating

AMS ^{14}C data are presented in Table 3.2. Radiocarbon analyses (in conjunction with typical sediment accumulation rates found in all other cores) demonstrate that the top of core LT-98-2 is not modern. The top of LT-98-12M is probably modern, although alternative age interpretations exist for the sample dated at 3-4cm which imply a hiatus at the top of the core. Eight ultramodern age dates (i.e. ^{14}C values greater than 1950, corrected for 20th century fossil fuel input of radiogenically "dead" carbon, and implying post-beginning of large-scale atmospheric nuclear testing) for cores LT-98-18, LT-98-58, LT-98-37, LT-98-82, and LT-98-98 are all consistent with the age models derived from the ^{210}Pb, although it is probably not possible to identify with precision an ultramodern "date" from these data, given both analytical uncertainties and uncertainties about the post-test ban falloff in atmospheric ^{14}C for this part of the world. With two exceptions (LT-98-58M @18-19cm and LT-98-82M @27-28cm), other ^{14}C age determinations are consistent with ^{210}Pb age models, and provide additional control for the geochronology of the lower parts of several cores. In the two cases where ^{14}C dates are not in agreement with the ^{210}Pb age model, the latter has been adopted and the former assumed to represent reworked older material. Core LT-98-2M displays extremely slow rates of average sediment accumulation, more typical of offshore-sills of Lake Tanganyika (~0.05-0.25 mm/yr), although the rate increases upwards, and substantially so after ~1100 A.D., and then declines again in the uppermost part of the core. Given the indications of excess sedimentation disturbance evident in parts of this core, and the core site's location on a large, distal bench (removed from regular sediment input), it may be that this site has experienced pulsed intervals of sedimentation (corresponding to a few decades around the radiometrically-dated horizons, separated by unrecognized hiatuses. For the purposes of this study, and for lack of an reasoned alternative, we have assumed a linear interpolation of ages between dated horizons , but the strong possibility exists that many events attributed with an "age" that are recorded in this core, may in fact have occurred much before or after that time.

Contamination by C-bearing glass (with infinite ^{14}C age) occurred in two samples, from cores LT-98-12M and LT-98-18M. For the latter of these no useful age information can be extracted. For the former however, contamination was minor, and the obtained calendar age of 1406 AD is consistent with rates of sediment accumulation encountered at the top of the core. The absolute sediment accumulation rates in this core are slightly slower than other undisturbed deltaic sites (~0.6-0.8mm/yr), although the questionable age determination on the 36-37cm contaminated sample allows the possibility that higher rates occurred prior to the mid 20th century.

A reversal in apparent ^{14}C ages was obtained from two samples (18-19cm and 37-38cm) in core LT-98-58M. However, both of these radiocarbon year "ages" have multiple calendrical ages associated with them and we have therefore chosen the pair that is most congruent with the ^{210}Pb chronology and internally consistent between the samples.

Table 3.2. AMS ^{14}C dates from samples analyzed by this project. All reported uncorrected ^{14}C ages are relative to 1950, and corrected ages are in calendrical years A.D (B.C.).

Table 3.2 AMS ^{14}C dates from samples analyzed by this project

AA #	Core # (LT-98)	Material*	Depth (cm)	$\delta^{13}C$	Fraction Modern	1 sigma	^{14}C Age B.P.	1 sigma	Preferred calendar age AD (BC)	Alternate calendar age(s)
32722	2M	p.f.	3-4	-26.2	0.9564	0.0071	360	60	1488-1653	-
29099	2M	t	19-20	-27.9	0.8844	0.0045	985	40	1042-1158	-
32721	2M	p.f.	34-35	-26.8	0.7321	0.0049	2505	55	(764-603)	(594-408)
32726	2M	t	42-43	-28.3	0.6008	0.0043	4095	55	(2829-2471)	-
30558	12M	l	3-4	-27.2	0.9679	0.0064	260	55	1936-1954	1738-1807, 1649-1681
33152	12M	p.f.	9-10	-25.4	0.8709	0.0205	contaminated			
33153	12M	p.f.	36-37	-23.3	0.9392	0.0133	500? (max. age-partly contaminated)	110	1406	
30559	18M	p.f.	1-2	-25.8	1.1327	0.0131	post-bomb (early 90s?)			
33150	18M	p.f.	18-19	-20.9	0.8767	0.014	contaminated			
33151	18M	p.f.	39-40	-25.3	0.8723	0.0126	contaminated			
30561	58M	p.f.	2-3	-18.4	1.0343	0.0088	post-bomb (early 50s?)			

32719	58M	p.f.	18-19	-25.2	0.9647	0.0086	290	70	1776-1804	1635-1677, 1940-1954
32728	58M	p.f.	37-38	-27.8	0.9744	0.0071	210	60	1718-1820	1664-1711, 1830-1882, 1914-1954
30560	37M	p.f.	3-4	-27.8	1.1450	0.0079	post-bomb (early 1990s?)			
32720	37M	p.f.	30-31	-24.6	0.9616	0.0067	315	55	1631-1667	1527-1559
32724	37M	p.f.	43-44	-24.4	0.09469	0.0071	440	60	1428-1653	
30562	98A	l & s	9-10	-28.0	1.1367	0.0064	post-bomb (early 1990s?)			
	98A	g.f.	18-19	-17.6	1.3192	0.0073	post-bomb (mid-late 70s?)			
	98A	l & s	34-35	-20.0	1.2276	0.0088	post-bomb (late 50s/early 60s?)			
30563	82M	p.f.	3-4	-26.3	1.14	?	post-bomb (early 1990?s)			
	82M	p.f.	6-7	-24.2	1.1399	0.0138	post-bomb (early 90s)			
32729	82M	g.f.	27-28	-13.9	0.9487	0.0141	420	120	1642	1412-1448

* Abbreviations for plant materials. p.f.=indeterminate terrestrial plant fragment, t = twig, l = leaf, l & s = leaf plus seed, g.f. = grass fragment

3.4 Sedimentology

Sedimentologic profiles (Grain size, Total Inorganic Carbon, Total Organic Carbon and Charcoal abundance) for the seven study cores are shown in Figures 3.20a, 3.21a, 3.22a, 3.23a, 3.24a, 3.25a and 3.26a and raw data are given in Appendix 3.

3.4.1 Granulometry

Several cores show pronounced changes in grain size through time which may be indicative of variations in watershed sediment discharge. The three Mahale Mtn drainage cores (two Lubulungu River delta cores plus one Kabesi River delta core) can be directly compared, although their chronologies are dissimilar. LT-98-2M displays an abrupt fining about 700B.C. , which corresponds closely with changes in a number of other indicators in the same core discussed below between 40-30cm downcore. A secondary fining event occurred about 400-500A.D. Low concentrations of sand occur throughout the lower portion of LT-98-12M. A modest increase in sand input occurs after about 1850 in LT-98-12M. LT-98-18M displays a slight increase in coarser-grained sediment, coincident with the increase in sedimentation rate dating from the early 1960s (more easily seen in Appendix 3 data than on Figure 3.22a).

Among the Gombe area cores, LT-98-58 shows a slight increase in coarse grained material input beginning in the late 19th century. A systematic decrease in the proportion of coarse sand is evident in the Mwamgongo core (LT-98-37), with pronounced declines in the late 18th and early 19th century (coincident with increased sediment accumulation rates). In Burundi, the Nyamuseni core (LT-98-98A), a relatively sandy core, does not show any clear trends upcore. However, the finer-grained Karonge/Kirasa core (LT-98-82) shows a notable upcore decline in sand, particularly after the early-mid 19th century.

3.4.2 Loss On Ignition (TOC and TIC)

Total organic carbon (TOC) values ranged between ~5-15% in all cores and show no consistent differences between localities. In contrast, calcium carbonate (the dominant source of TIC) concentrations are generally low (1-5 percent) in the Mahale and Burundi cores, but much higher in both Gombe area cores, probably reflecting overall lower fluxes of siliciclastic sediments into the areas offshore from these small watersheds.

Both TOC and TIC show increases in the LT-98-2M core that correlate with upcore granulometric changes to finer textures. TOC values remain high throughout the rest of the core (~15%), whereas TIC values (driven by mollusc fragment and, to a lesser extent ostracode concentration) subsequently decline after 1000-1100AD, probably as a result of initial increases in productivity of carbonate-producing organisms, followed by siliciclastic dilution caused by higher rates of mud input (this is consistent with the granulometric data, and ^{14}C age data).

Core LT-98-12M displays high TOC values and low TIC values throughout the core. Both vary slightly, in ways that are not evidently correlated with other variables. LT-98-18M shows slightly lower TOC values, which decline systematically above 20cm (1899). TIC content increases slightly at the same time, but is low throughout the core. Because relative sedimentation rates are known for this core, and increase about 3x after 1961(13cm), these proportional values can be transformed into flux data. Slight declines in TOC and slight increases in TIC actually represent major increases in flux rates of both calcium carbonate and organic matter over the past ~40 years at this site. In the case of the TIC this probably represents *in situ* carbonate production, since there is no source of $CaCO_3$ particulate matter in the Kabesi watershed. In the case of TOC the increase could reflect increased aquatic organic matter accumulation, increased terrestrial organic inputs, or some combination of the two.

LT-98-58M displays moderately high (7-9%) TOC throughout the core, with no systematic trends evident. TIC is relatively high (though also very variable) throughout the core. It (TIC) shows a marked decline in the mid 19th century, followed by a dramatic rise after 1930. Relatively constant sedimentation rates throughout this core suggest that both TOC and TIC curves are proportional to actual flux rates on an annual basis.

LT-98-37M displays high values of TOC throughout the core (~10%). A single sample from the late 1940s has very high TOC values. LT-98-37M also displays some of the highest TIC values seen in any core, although these decline dramatically starting in the 1920s and reach levels comparable to other sites (<5%) by the 1950s. As with core 58M, relatively constant sedimentation rates throughout the ^{210}Pb-dated portion of the core show that these TOC and TIC values are proportional to annual flux.

Core LT-98-98 displays relatively constant and moderately high proportions (6-9%) of TOC throughout the core, coupled with consistently low TIC values (reflected in the near absence of shelly fossils in this core). Dramatic upcore increases in sedimentation rates indicate that the flux of both of these variables per annum was increasing in proportion to total sediment accumulation rates (i.e. several fold increases over recent decades, thought problems in dating this core preclude a precise estimate of when these changes occurred). Similar patterns in core LT-98-82M of constant TOC (here slightly more abundant proportionately) and TIC proportions in the face of dramatically increasing sedimentation rates also imply increased flux rates. Abundant terrestrial plant debris throughout the upper part of LT-98-98M (and to a lesser extent in LT-98-82M) suggests the TOC increase is primarily driven by allochthonous organic matter coming from terrestrial sources. The increase in TIC flux on the other hand is almost certainly autochthonous, since there is no source for particulate calcium carbonate in the watershed, but given the extremely low abundances of both molluscs and ostracodes, this cannot represent an increase in benthic consumers. Small needle shaped rosettes of aragonite are extremely abundant in the surficial sediments of this area and are thought to form in the water column. These probably represent the bulk of the TIC observed in these sediments and their increase may reflect increasing surficial waters primary productivity rates accompanying the increasing sediment input. Based on the sedimentation rate studies this process was clearly underway after 1961, but indications of an earlier rise (late 18th century) are also evident.

3.4.3 Charcoal

Charcoal fragment abundances are very high (~10^3-10^4 gm^{-1}) throughout most of the cores (except LT-98-18 and, surprisingly, LT-98-82M), consistent use of fire in land clearance and the ubiquitous usage of fire for cooking and charcoal production. Uncontrolled wild fires may also be contributing to these high fluxes (such fires are commonly observed in the Tanzanian coastal woodlands and grasslands today, although in the more heavily settled regions of Burundi they are much less common. In most cases charcoal abundance cannot be directly or simply correlated with patterns of land use in the immediate adjacent watersheds. The fact that charcoal floats may cause its distribution pattern to be strongly skewed by current patterns active at the time of transport into the lake. At the present time we do not know how charcoal input into the sediments of Lake Tanganyika from cooking fires or charcoal production might differ from the pattern produced by uncontrolled wildfires or intentionally-set fires for land clearing. Understanding such differences might help clarify the confusing patterns observed in our cores. We also do not know the extent to which anomalously elevated values of charcoal in these profiles may represent single large fire events, or alternatively, integrate longer term changes in charcoal input.

LT-98-2M shows a strong signal of increasing charcoal in the upper part of the core, beginning ~0-100AD (coincident with the first occurrences of ostracodes and molluscs in the core, and accelerating after ~1200-1300AD), consistent with other indications of increased sedimentation rates and watershed disturbance. Values of over 1000 gm^{-1} occur in some samples. In core LT-98-12M, a decrease in charcoal abundance above 30cm (late 15th century AD?) is then followed by a less dramatic rise in the upper 15cm (mid 18th century). A dramatic increase in abundance and flux is evident in the uppermost sample.

LT-98-18M contained much less charcoal than the other samples. Relatively high abundances prior to the 1830s are followed by a significant decline to very low abundances during the late 19th and early 20th centuries. An increase in charcoal (and charcoal flux) in the early 1930s was followed by another decline in charcoal after the early 1980s.

Charcoal abundances are extremely high in the LT-98-58M core (Nyasanga/Kahama-Gombe area) and rise to extraordinary levels at the core top. This result was unexpected, as the area is protected from intentional burning today (high values occur in both the pre- and post National Park eras). Very high values occur in samples from both the late 18th/early 19th century, and again during the 20th century. The high values of the late 20th century suggest that charcoal must be transported by floatation over distances that exceed that separating this study site from the park boundary (i.e. several kilometers), or alternatively, that wildfire within the park is for some reason anomalously high. We consider the latter explanation unlikely, because the difference between park and "non-park" in terms of watershed land usage and seasonal burning is dramatic in this area. This signal of sediment input for floating fractions from areas outside of the immediate vicinity of this small delta is also evident in the pollen record of this site, discussed below.

LT-98-37M displays moderately high values of charcoal throughout the core. Also unexpectedly, these values decline slowly but continuously throughout the core interval (i.e. 17th century to modern).

Core LT-98-98M displays relatively high and constant concentrations of charcoal in the lower part of the core. These give way to a spike (perhaps a single large fire?) at 15.5cm and then rather abruptly (mid 1990s) declining values to the top of the core.

Core LT-98-82M displays relatively low abundances of charcoal throughout much of the core (in some cases to very low levels), except for two levels (36-27cm = ~17th Century and towards the core top (late 20th Century). Given the highly disturbed nature of this watershed this was initially surprising, particularly given that flux rates declined dramatically in the late 19th century and remained very low for most of the 20th century. A marked increase is observed only in the uppermost two samples (early 1990s). Low to very low levels in these northern Burundi sites, which are known from historical records to have been heavily populated for at least most of the 20th century (and where uncontrolled or large-scale burns are relatively uncommon), suggest that burning of woodlands for land clearance and/or uncontrolled fires, rather than household cooking fires, are the principal sources of charcoal in our sediments.

3.5 Paleontologic Records by Core

Stratigraphies of summary ostracode and pollen statistics, sponge spicule counts and fish bone counts are given in figures 3.20a, 3.21a, 3.22a, 3.23a, 3.24a, 3.25a and 3.26a and raw data are given in Appendix 3. Profiles for individual ostracode species are given in figures 3.20b, 3.21b, 3.22b, 3.23b, 3.24b, 3.25b and 3.26b, with each figure subdivided into common (>1% of aggregate count for all samples) and rare taxa (<1%). Figures 3.20c, 3.21c, 3.22a, (fewer variables were collected for this core, so they are plotted with the summary diagram), 3.23c, 3.24c, 3.25c and 3.26c illustrate the taphonomic data collected for fossil ostracodes. Palynologic profiles are presented in figures 3.20d, 3.21d, 3.22c, 3.23d, 3.24d, 3.25d and 3.26d.

3.5.1. Ostracodes

Ostracode abundances vary greatly within and between cores ($<10^1$ to $>10^4$ gm^{-1}).

In core LT-98-2M total ostracode abundance is low to moderate (<500 gm^{-1}), and is generally positively correlated with decreased grain size and increased TOC (Fig. 3.20a). Ostracodes are absent in the lower 21 cm of the core (49-28 cm), prior to ~0-100AD. Numbers per gram gradually increase upwards from zero at 28 cm, a short distance above the sedimentologic change, to near the surface (3-4cm) (late 15th-mid 17th century) where they decline slightly. Based on interpolated sedimentation rates alone (mm yr^{-1}), this gradual initial increase in ostracode abundance lags the initial increase in fine detrital sediment by about 750 years, but corresponds very closely with the secondary fining event that eliminated almost all sand input as well as other sedimentological indicators previously mentioned.

Ostracode species richness (number of species present) ranges from 14 to 34 species among sample, although over 47 species occur throughout the core. Fifteen species are common on the central plain of the Lubulungu River delta (Fig. 3.20b(i)). The rest are fairly common (occur periodically) to rare (occur once or twice) in the record. *Romecytheridea* sp. 13 is, by far, the dominant species (its proportional abundance therefore is negatively correlated with the cumulative abundance of all other taxa) and is represented largely by juvenile individuals. Several common or fairly common species display upcore increases (*Gomphocythere downingi*, and possibly *Mecynocypria emaciata*, *Cypridopsis* sp. 5, *Tanganyikacypridopsis depressa*, and *Tanganyikacypridopsis* sp. 3 *)*, others decline upcore (*Mecynocypria opaca*, *Mecynocypria parvula and Allocypria* sp. 5 and possibly *Gomphocythere coheni*).

Ostracode diversity (Fisher's-" diversity index) shows high and relatively constant diversity from the first appearance of ostracodes to about 13 cm from the surface. Above this, diversity decreases upcore, associated with the disappearance of numerous rare taxa. The Jaccard’s similarity index between adjacent samples is low throughout the core with no apparent trends, indicating substantial faunal turnover between sampling intervals.

Seven taphonomic features are recorded for ostracodes: fragmentation, encrustation, abrasion, redox index, % carapaces, % adults, and the right/left valve ratios (Fig. 3.20c). Fragmentation is low throughout the core and decreases upwards, indicating that ostracode populations have not been heavily damaged or sorted by wave activity. Similarly, abrasion is minimal, and there is no obvious right/left valve bias, suggesting little transport. Diagenetic features like encrustation and the redox index are low implying that there are no significant burial effects on the valves. The low proportion of carapaces probably reflects simple-post-mortem disarticulation (most Tanganyikan species have weak hinges on their valves). Low adult ratios suggests that few individuals are maturing, typical of deep water, stressed habitats like this core site and all others in the study.

Core LT-98-12M is marked throughout by very low ostracode abundances. This difference from nearby core 2M in part no doubt arises from the difference in age of the cored intervals, but is probably also a result of the slightly greater water depths of core 12 (126m vs. 110m), placing the former core very close to the depth of oxygen depletion, where both ostracodes and molluscs are typically absent. Differences may also be attributed to slight variations in water depths for the different intervals represented by these two cores. A notable upcore increase occurs at about 13 cm above which ostracode abundances remain relatively higher.

Ostracode species richness ranges from 8 to 36 species among samples, although over 46 species occur throughout the core. However, the very low abundances of ostracode fossils precluded full 500 counts for all of the 12M samples, so differences in species richness and diversity are probably artifacts of necessarily unequal sampling. Fifteen ostracode species are common (Fig. 3.21b(i)). *Mecynocypria opaca* is the dominant species, present at high proportions throughout most of the core (except at the top). *Gomphocythere* species are generally common and collectively decline upcore, particularly for the abundant *G. curta*. Species showing marked upcore increases include *Mesocyprideis* sp. 2B, *Romecytheridea ampla*, and possibly *Candonopsis* sp. 2 and *Mecynocypria connoidea.* The latter three species appear abruptly in the core at 15.5cm (mid 18th century), a point of major assemblage changes (many species peak and then decline here). Both the upcore declines and increases (as well as an overall increase in abundance-Appendix 3) correspond with upcore changes in sedimentology (slight increase in coarser sediment, and slight decrease in TOC), dating to the mid-late 19th century.

Fisher's- diversity is higher at LT-98-12 than in the LT-98-2 core, particularly notable since the total abundance of ostracodes was so low at the former site. Taken together, the two cores indicate a general increase in species diversity and decrease in dominance over the past 2500 years, with a particularly notable increase in diversity after the late 16th century (the uppermost part of this rise, recorded in 12M possibly being an artifact of small sample size). The Jaccard Index is very low (0.2-0.4) in the lower part of the core, possibly indicating extreme faunal turnover (alternatively also a possible function of small sample size), but increases substantially above 20cm (17th-18th Century?), perhaps indicative of greater stability in community structure after this time.

Eight taphonomic features are recorded for ostracodes: fragmentation, encrustation, coating, abrasion, redox index, % carapaces, % adults and the right/left valve ratios (Fig. 3.21c). The results are similar to those for core LT-98-2M, indicating good preservation of a highly stressed population, with relatively minor *post-mortem* reworking of valves.

Ostracode abundance in core LT-98-18M is highly variable, with relatively low levels in the lower part of the core (18th/19th century), giving way to slowly increasing values in the early 20th century, and a rapid rise in the early 1960s (coincident with a significant increase in sedimentation rate (Fig. 3.22a). Species richness also declines gradually upcore, with many species declining after 1900. The Jaccard Index of Similarity is relatively constant and moderately low (0.3-0.5) throughout the core, indicating substantial faunal turnover. Increasing dominance by *Romecytheridea* sp. 13, especially after 1960 results in upcore declines in Fisher's- index and the similar Shannon-Weiner diversity index (Fig. 3.22b). This increasing dominance by this single species, coupled with increasing total ostracode abundance, reflects an extraordinary increase in the flux of *Romecytheridea* sp. 13 valves into the core site. Simultaneously, a vastly greater proportion of these individuals are unfragmented juveniles. There are two possible explanations for such fossil population. Our preferred explanation (because of its consistency with other factors considered in the discussion section), is that they may have floated and been rafted in very large numbers. This species when alive is most common in shallow mud bottoms, and the valves show little sign of breakage (a probable outcome of traction or bed load transport). This type of assemblage change would then represent the offshore accumulation of light, easily transported juvenile valves that were derived from abundant and increasing nearshore benthic production. Alternatively the large proportions of monospecific juveniles may represent ecologic stress on a community, with many species disappearing and individuals of the dominant species incapable of maturing to the adult phase. Regardless of which explanation is correct (or if both were operative) this must have been occurring through a time interval (starting in the early 20th century and intensifying in the early 1960s) when community structure was becoming simplified through some disturbance factor. Community turnover is high but relatively constant throughout the core.

Core LT-98-58M displays moderately high but erratic abundances of ostracodes through the core (Fig. 3.23a). Abundances (and fluxes as well, since sedimentation rates were relatively constant through the core) were high in the early interval (before ~1800), then declined significantly throughout the 19th century and then rose, albeit erratically, in the mid 20th century. Species richness is extremely high in this core (higher than any other core site), and shows a small but notable increase over time, particularly after ~1915 (Appendix 3). Jaccard indices were surprisingly high throughout this core, indicative of substantial community stability in terms of presence/absence. Jaccard results from this locality stand in contrast to both other low impact sites investigated in this study, and to earlier work (Cohen, in press) which had suggested that substantial faunal turnover is commonly coupled with high diversity at low impact sites.

The continuity of species occurrences (presence/absence) in core 58 notwithstanding, the individual abundances of species changes markedly upcore. The absence of dominance by any given species is evident in the relatively low proportions found among all common ostracode species (Fig. 3.23.b(i and ii)). Some species show long-term trends in abundance, for example upcore increases in *Gomphocythere curta* and *Cypridopsis* sp. 8, and declines in *Gomphocythere downingi*, *Mecynocypria opaca*, and, since the early 19th century, *Mecynocypria obtusa* and *Tanganyikacypris matthesi*). Significant dominance changes, associated with the aforementioned increases and decreases, occurs in the late 19th or early 20th century. For most other species the general pattern is one of erratic fluctuations.

Taphonomic data indicate the ostracode accumulation is probably a life-assemblage (Fig. 3.23.c). Fragmentation is low and constant throughout the core and there is a 1 to 1 ratio of right/left valves throughout the core. Abraded valves (always <10%) are only recorded between 33 and 21 cm. Both variables indicate *in situ* deposition. Diagenetic features like encrustation, coating and the redox index are minor and sporadic, indicating that there are not post-depositional effects despite the relatively high total concentration of $CaCO_3$ in the core. As with the other samples, the low percentages of adults are reflective of the oxygen-stressed, deep water environment.

Ostracode abundances in core LT-98-37M decline dramatically from very high levels during the late 17th and early 18th century, and then remain stable until the mid 20th century (there is also a marked decline in the uppermost sample) (Fig. 3.24a). Some, although not all of this pattern can be explained by increasing sedimentation rates after the early 19th century (i.e. ostracode flux must have also declined during this interval). This pattern shows some correlation with the timing of declining influx of coarser sediment we have recorded, and may be indicative of changing quality of organic matter being delivered to detritus feeders from the watershed (the quantity of TOC remains constant). As with the other Gombe area core, species richness is very high (typically 35-40 species per sample), and Fisher's diversity index is high and constant throughout the core, but there is also substantial faunal turnover throughout the core. Several species decline through the core interval (notably *Gomphocythere cristata, Allocypria. sp. 5, Mecynocypria opaca, Candonopsis* sp. 2, *Cypridopsis* sp. 5 and 6, and *Candonopsis*. sp. 11, *Tanganyikacypridopsis* sp. 3, *Limnocythere* sp. 8. The latter three species, in addition to several other rarer ones, disappear entirely from the core record between the late 19th and early 20th century. These species are replaced over the past 100 years by increases in *Archaeocyprideis tuberculata*, *Mesocyprideis* sp., *Gomphocythere downingi*, *Allocypria inclinata*, *Allocypria* sp. cf. *A. reniformis*, *Candonopsis* sp. 2, and *Romecytheridea* sp. 13. The latter species, a good indicator of human disturbance and increasing silt loading, shows a marked rise in the uppermost samples (post 1950s) at this site. This change is reflected in the Jaccard Index, which is moderately low throughout most of the core (0.4-0.5) but which shows a major increase in turnover (values declining to 0.3-0.4) after the late 19th century.

Six taphonomic features are recorded for ostracodes: fragmentation, encrustation, coating, percent carapaces, percent adults and right/left valve ratios (Fig. 3.24.c). Fragmentation is low and constant throughout the core. Lack of abrasion is consistent with low fragmentation suggesting *in situ* deposition. Diagenetic features like encrustation and coating are low and occasional (redox conditions were not recorded), indicating that post-depositional burial effects are minimal despite the relatively high concentration of $CaCO_3$ throughout most of the core. The low percentages of adults is again consistent with deep water stress.

Core LT-98-98M was nearly barren of ostracodes (Fig. 3.25.a). Two samples at the top of the core (probably both from the 1990s) contained low abundances of valves, and correspond with the simultaneous appearance of other rare benthos and fish. Both samples were highly dominated by a small number of species, although the species richness of the surface sample was significantly higher than the lower (3.5cm downcore) ostracode-bearing sample (Fig. 3.25.b(i)). The Jaccard Index is very low comparing the two samples in which ostracodes were found, in part reflecting the extremely low diversity encountered in the lower, ostracode-bearing sample (Jaccard is very sensitive to unequal diversity levels).

Taphonomic features of the LT-98-98M samples are substantially different from other cores, with abundant carapaces and adults recorded (Fig. 3.25.c). Fragmentation and abrasion are both low suggesting the assemblage was not significantly reworked. The difference in adult and carapace abundance in this core can probably be attributed to the core site's relatively shallow depth (60m) compared with the other more oxygen-stressed core localities.

Core LT-98-82M, like the other northern Burundi core, has few ostracodes, and the upper 25cm (i.e. post-1840) is barren (Fig. 3.26.a). Because the number of individuals encountered was so low, species richnesses cannot be directly compared with the Tanzanian cores, and Jaccard Indices, although plotted and low, are essentially meaningless. A small number of species dominate these lower core samples, with erratic frequencies, as in other cores (Fig. 3.26.b. Seven taphonomic features are recorded for ostracodes: fragmentation, encrustation, coating, abrasion, percent of carapaces, percent of adults and right/left valve ratios (Fig. 3.26.c). Percentages of fragmented, encrusted, coated and abraded valves are all relatively high in comparison with other cores, and right/left valve ratios are erratic, all suggesting that the assemblage may have been significantly transported and/or reworked from older deposits.

Comparison of stratigraphic profiles for the three core sites where upcore sedimentation rate increases are evident (LT-98-18, LT-98-98, and LT-98-82) suggests that a core low diversity assemblage of relatively common species persists (and perhaps thrives) under high sediment accumulation rate conditions. Listed from apparently most tolerant, these include *Romecytheridea* sp. 13 (apparently the most tolerant species), *Mesocyprideis* sp. 2B, *Gomphocythere coheni* (both very tolerant), *Mecynocypria opaca*, *Mesocyprideis irsacae*, and *Gomphocythere downingi.* Attempts to generalize about species which are intolerant to high sediment accumulation rates are confounded by both geographic range variability among species and the general patchiness of rare ostracode species observed around Lake Tanganyika (Cohen, in press). This combination of extreme dominance in some assemblages and patchiness was reflected in our inability to obtain meaningful data from multivariate statistical analyses of assemblages (both cluster and correspondence analyses were conducted). In both cases, local signals, controlled by the co-occurrence of a set of species that often were completely unrepresented at other localities.

3.5.2. Pollen

Pollen preservation in the study cores was generally quite good. As is typical of regional pollen floras, grasses predominate the spectra, even from currently forested or woodland regions. Grass pollen percentages range between 40-80%. Despite the deltaic setting of the coring sites aquatic and emergent marsh taxa are generally rare, reflecting the very limited development of marshland or littoral vegetation typical of the steep coastline present at all of these study areas. Low percentages of arboreal pollen taxa (from <1% to ~20%) were recorded in most cores. The presence of native *Lycopodium* unfortunately makes it impossible to calculate pollen fluxes from these samples.

Core 2M (fig. 3.20d) provides the longest duration vegetation record of our study. The core record is dominated by grass pollen (*Poaceae* (*Gramineae*)). It gives clear indication of a significant decline in forest and woodland taxa (*Celtis, Oleaceae, Podocarpus, Rosaceae, Polypodiaceae*), replaced almost entirely by grasses. This change appears to have been staged. Its earliest signals start about 600B.C. (35cm), and is coincident with the first rapid changes in lake sedimentological and paleontological indicators. A second phase of reduction in arboreal pollen types occurs about 0-100AD (~30cm), coincident with other lake changes. High elevation conifers (*Podocarpus)* decline throughout this interval. A minor increase in arboreal pollen near the top of the core may reflect a partial reversal in the extent of forest cover, or may be part of the similar long term pattern of arboreal pollen increase observed in other cores over the last few centuries (discussed below). Unlike the other cores discussed below, fern spores (Pteridophytes) show no consistent trends in abundance over time.

Cores 12M, 18M, 58M and 37M show similar patterns to each other and therefore are best discussed as a group. All are dominated by grass pollen at all levels, and all show a consistent trend of declining grass pollen upcore, replaced by forest indicator taxa, and, for all cores except 12M, substantial increases in pteridophyte spores as well. Increasing herbaceous plant pollen from groups such as the Compositae and Commelinaceae also contribute to the trend of decreasing grass pollen in these cores.

The timing of this change varies between cores. For core 12M (Figure 3.21d), evergreen taxa (dominantly low-elevation species) pollen percentages (e.g. *Acalypha, Macaranga, Mallotus, Moraceae* and *Celtis*) increase from less than 1% to about 3%, and total arboreal taxa increase from about 5% to 20%, with the most marked change occurring starting in the early 20th century (precise dating is weak in this core), or 6cm below the core top. A few woodland taxa, such as *Brachystegia, Isoberlinia* and *Commiphora*, are also represented, although at low values (0-1%). In core 18M (Figure 3.22c) the grass decline is more precipitous and its timing can be better constrained. Here the decline starts in the late 1950s/early 1960s, coincident with major sedimentological and lake paleoecological changes noted earlier. Upper elevation woodland and montane forest taxa such as *Oleaceae* and *Podocarpus* in particular increase substantially towards the core top. Euphorbiaceae pollen and pteridophyte spores also increase markedly over the last 30-40 years.

In cores 58M and 37M (Figures 3.23d and 3.24d) declines in grass pollen appear to occur over a much longer interval, starting in the 18th century (58M) and perhaps as early as the 16th century in 37M. As with the other cores, the long term decline in grass pollen is accompanied by increasing arboreal pollen and pteridophyte spore percentages. Arboreal pollen declines slightly at the top of 58M, where pteridophytes increase dramatically. In the upper portion of 58M (post 1950s) *Acacia*, *Brachystegia*, *Podocarpus* and Polypodiaceae increase markedly. In contrast, woodland tree taxa pollen declines during the 20th century in core 37M.

Core 98M (Figure 3.25d), which covers the shortest time interval of any core studied, shows no consistent trend of grass pollen replacement by arboreal taxa. It does however, show the fern spore increase noted in other core tops. The much longer record from the nearby 82M however shows the same long-term decline in grass pollen and increases in arboreal pollen and ferns observed elsewhere. In 82M this trend is evident from the base of the core (early 18th century), with particularly notable increases in low elevation euphorbs (*Acalypha, Alchornea* and *Mallotus*) and *Celtis*, but of course may have been underway earlier than that. Myrtaceae percentages increase dramatically after the 1930s, consistent with the widespread planting of *Eucalyptus* in Burundi starting in the 1930s (P. Ndabaneze and K. West, pers. comm., 1999). Native Myrtaceae were clearly present prior to the first introductions of *Eucalyptus* in the late 1920s, but the two types could not be distinguished in this study. Myrtaceae is also abundant in 98M but absent or extremely rare in other cores, consistent with the much more widespread planting of *Eucalyptus* in Burundi than in Tanzania.

The presence of *Acacia* pollen, even at relatively low abundances, is noteworthy in the 82M core. Acacias are uncommon plants in the modern Karonge/Kirasa watersheds, but occur abundantly in the Ruzizi River basin, about 30-40km to the northwest. The occurrence of *Acacia* pollen throughout the middle and upper parts of this core suggests some relatively long distance transport of pollen into the core area, possibly by wind, but also perhaps as a result of coastal transport of suspended sediment. The fact that no well defined northern margin of an offshore delta exists for the Karonge/Kirasa (shallowing continues all the way to the Ruzizi) is consistent with the second explanation, although clearly both processes could be involved. These data also show the scale of spatial averaging of arboreal pollen "rain" that the core sites can be expected to record.

At least two explanations can be suggested for the overall pattern of increasing arboreal and fern pollen and decreasing grass pollen observed in multiple cores and over a wide area. The first possibility is that these data record a real trend towards increased forest and/or fernland cover, at the expense of grasslands, over the past few centuries. This explanation seems to us implausible. First, there is no historical record of such forest expansion (what little data exist would argue the opposite). A "literal" interpretation of increasing forest cover also challenges us to examine the relative proportions of pollen types at the core tops, which for all cores except 2M, record late 20th century conditions, the only time period for which we can examine the proportions of vegetation types directly. Comparisons made in this way show that the most deforested watersheds (Karonge/Kirasa and Nyamuseni) show little difference in terms of proportions of arboreal vs. grass pollen from the least (Lubulungu and Nyasanga). All core tops have arboreal pollen percentages in the 10-20% range. Thus we reject this hypothesis as being too simplistic to adequately explain the data.

An alternative hypothesis is that the upcore increases in forest pollen are actually a reflection of differential pollen production and are in fact consistent with progressive land use conversion to more intensive, subsistence agriculture. This interpretation at first glance may seem surprising and counterintuitive. Particularly where slash and burn or rotating types of agriculture are pursued, agriculture might be expected to increase the area and pollen production of fallow-year elephant grass, *Andropogon*, *Eragrostis* etc. However a consideration of both the nature of the agricultural crops involved and the nature of agricultural practices in these heavily settled areas suggests an alternative scenario. First, almost all of the agricultural species involved in the region's forest/woodland to agriculture conversion (casava, bananas, mangoes, agricultural legumes, tea, coffee and sisal) produce very small quantities of pollen. The same is true unfortunately of the common *miombo* woodland trees (e.g. *Brachystegia*, *Julbernardia* and *Isoberlinia*) that grow at low and mid- elevations where human settlement is most intense. Second, agricultural lands are used extremely intensively over long time intervals, often to the point of soil nutrient depletion, because of the scarcity of available and suitable land. Continual weeding of subsistence plots may have significantly limited the growth of nonagricultural species, and this process may have been progressive over time. The remaining pollen flux into the lake would then have increasingly been derived from progressively more distant (and higher montane) sources, away from lowland clearance. These areas are dominated by trees and fernlands. A test of this hypothesis would require knowing the absolute flux of the pollen "rain" into the core sites, since the model predicts that overall pollen accumulation rates should be declining to account for a relative increase in the proportion of arboreal and fern pollen/spores. Unfortunately, our inability to make use of the *Lycopodium* spike (because of the presence of native *Lycopodium* in the samples), means that the cores would have to be re-sampled, re-processed and recounted to accomplish this test, which is beyond the scope of our current study or time/resources available.

Another factor of importance in interpreting the Lake Tanganyika pollen profiles is the likely mode of transport for different pollen types, as this will undoubtedly play a role in where pollen of different species will ultimately be deposited. Pollen of *Poaceae* (*Gramineae*), and montane forest taxa such as *Podocarpus* and *Olea* are mainly wind transported. The occurrence of *Podocarpus* in particular throughout the Gombe area cores clearly attests to significant wind-transport since this conifer does not occur in the Gombe area today (the nearest regions of sufficient elevation to support this species are probably in southern Burundi). In contrast, evergreen forest taxa such as *Macaranga* and *Myrica*, woodland taxa such as *Brachystegia* and *Acacia*, and aquatic taxa such as *Typha* and *Cyperaceae* are primarily transported by water (DeBusk, 1998). Plant species from which pollen taxa originate can live in variable habitats. Keeping in mind the variation in transport vectors and variable habitats of taxa, no single pollen source area can be defined for the pollen diagram. The composition of a pollen diagram at any point in the lake is thus a complex function of catchment vegetation and the position of the site relative to river discharges and wind currents (DeBusk, 1997). Interpretation for this study's pollen diagrams is both complex and difficult because the Lake Tanganyika catchment from which pollen enters the lake is both large and extends over 2000m of altitudinal range.

3.5.3. Molluscs

Mollusc fossils throughout the cores are primarily fragments that cannot be identified to species. In those rare cases where fragments are large enough to identify the species present invariably belong to the deep water detritivore group of endemic gastropods, including *Paramelania iridescens* and *Tiphobia horei*, and, less commonly, *Neothauma tanganyicense*.

Mollusc fossils in core LT-98-2M are absent in the lower part of the core (consistent with ostracodes) (Fig. 3.20.a). They first appear at about 25cm (~400-600AD, or somewhat after the first ostracodes) and then remain at moderate levels of abundance until ~1500-1650AD, when they increase dramatically. These high levels of abundance (and subsequent declines) may be correlative with the mollusc abundance peak at the base of the much more rapidly- sedimented LT-98-12M (Fig. 3.21a). Both cores have considerably higher mollusc abundances on average than any other cores studied.

No mollusc abundance data is available for core LT-98-18M. In both Gombe area cores (LT-98-58M-Fig. 3.23.a, and LT-98-37M-Fig. 3.24.a) molluscs are rare and occur only sporadically through the cores (none were accumulating in the 37M site prior to the 1930s).
Molluscs were almost entirely absent from cores LT-98-98A and LT-98-82M (Figs. 3.25a and 3.26.a).

3.5.4. Sponges

No keys exist to identify spicules of the nine species of sponge found in Lake Tanganyika, and therefore data is presented only as total abundances. Spicule abundances varied greatly both between and within cores, from 0 to $>10^4$ gm^{-1}.

In LT-98-2M spicule abundance varies inversely with grain size, total organic matter, charcoal and all other benthic invertebrate signals throughout the core (Fig. 3.20.a). This pattern strongly suggests that spicule abundance in this instance is related to suspended sediment flux (sponges are known in stream systems to be adversely impacted by high suspended sediment loads, as they are filter feeders, although other factors such as grazing may be more important in controlling their distribution in Lake Tanganyika). Two pulses of decline are suggested by the abundance evident in the core. An initial, major decrease started about 1900-1750B.C., and a further pronounced decline occurred after the 12th-13th century A.D. Flux data, suggests that the second decline may be in part an artifact of increased sedimentation rate and clastic sediment dilution (Appendix 3), although, as noted earlier, flux calculations are affected (and made less meaningful) by increasingly episodic sedimentation patterns. Spicule abundances, both in numbers per gram and as fluxes, are generally much higher in LT-98-12M (Fig. 3.21.a) than in 2M (particularly given the much higher sediment accumulation rates), and no correlations in abundance patterns are evident between the two cores.

In core LT-98-18M spicule abundance is intermediate between the other Mahale area cores, and shows less variability through the core interval (Fig. 3.22.a). An upcore decline at the base of the core is followed by slowly increasing abundances above ~21.5cm (late 19th Century). Much lower values (both absolute and normalized for flux) are observed in the uppermost sample (post-late 1980s).

The Gombe area cores display interesting contrasts with the Mahale cores and with each other (Figs. 3.23.a and 3.24.a). LT-98-58M has highly variable abundances of sponge spicules, with very high levels encountered in several samples near the bottom of the core (late 18th or early 19th century), followed by much lower abundances with little overall trend. LT-98-37 had very low spicule counts throughout the entire core. No spicules were found in the lower portion (prior to the early 17th century), and gradually increasing (particularly after the late 19th Century) but low values were found through the remainder of the core. No evidence was observed for declining abundances in recent decades adjacent to this small disturbed watershed.

Spicule abundance patterns from the two Burundi cores were also surprising. LT-98-98A is almost completely barren of spicules, However, spicules were relatively abundant and actually increased upcore in LT-98-82M. The timing of this increase (beginning in the early 19th century) corresponds with a general increase in sediment accumulation rate and fine-grained siliciclastics, and a decline in both ostracodes and fish fossils. Casual observation of littoral rock surfaces in this area shows that sponges are extremely common on the undersides of rocks in this region today, perhaps as a result of decreased grazing pressure from littoral fish populations.

3.5.5. Fish

Fossil fish bones occur at abundances of 0-10^2 gm^{-1} in most core material examined, often varying erratically between stratigraphically-adjacent samples. As of this writing the bones could not be identified to family, although our laboratory is working on resolving this problem, to allow separation of clupeids, centropomids and cichlids in future analyses. The one core with significantly higher abundances (LT-98-12M) can be explained by that core's extremely low average sedimentation rates (i.e. flux rates are comparable with other cores). Core 2M shows a general decrease in fish bone abundance throughout the core (this translates into a flux increase because of the higher sedimentation rates in the upper part of the core). None of the other Tanzanian cores showed any consistent trends through time. In contrast, the Burundi cores suggest very low abundances (or absence) of fish fossil accumulation through much of the core intervals. In LT-98-82M fish fossils disappear from the record after the 1840s, simultaneous with other indications of disturbance.

3.6 Stable Isotope Records

Our first attempt to analyze the $\delta^{18}O$ and $\delta^{13}C$ of ostracode shells failed due to their poor calcification. Valves of *Romecytheridea* sp. 13 and *Gomphocythere* n.sp. "downingi", *Mesocyprideis* sp. 2B, and *Mecynocypria opaca* were all very poorly calcified, resulting in insufficient material for isotope analysis. In the end we were able to combine 20 valves for each analysis. The CO_2 yields, measured during sample processing, suggest that there is only 2 to 4 micrograms of carbonate in each valve. This is one to two orders of magnitude smaller than the typical adult ostracode shell of comparable size. The reason for this poor calcification is not clear, especially as the lake water is clearly supersaturated with respect to calcium carbonate. Perhaps the shallow lake sediment environment is acidic due to the oxidation of organic material and this is causing dissolution of carbonates after burial.

The oxygen isotope composition of *Romecytheridea* sp. 13 from Core 2M is relatively constant in $\delta^{18}O$, ranging from +2.05 to +2.51 while $\delta^{13}C$ is more variable, ranging from -5.84 to -7.46 (Fig. 3.27a). In core 18M valves of the same species range in $\delta^{18}O$ from +2.15 to + 1.70 while $\delta^{13}C$ varies from -6.56 to -7.75 (Fig. 3.27b). We attempted to analyze three species from a single interval of core 37M, 43-44 cm depth. The sample of *Romecytheridea* sp. 13 failed due to small sample size, but good measurements resulted for *Gomphocythere* n.sp. "downingi", and *Mecynocypria opaca;* these data are in Appendix 6 data table.

The oxygen isotope composition of ostracode shells responds to the isotopic composition and the temperature of the water in which the animals grow. A number of studies have shown that ostracodes are offset by +1 per mil from isotopic equilibrium in the precipitation of their shells (Dettman *et al*., 1995a; Xia *et al*., 1997). This offset has been documented in a number of taxa, including some from Lake Tanganyika (Dettman *et al*., 1995b). Because the seasonal cycle in temperature is small in Lake Tanganyika surface waters and because we were forced to use 20 individuals for each sample (probably mixing shells from different seasons) we assume here that the $\delta^{18}O$ of the ostracode sample primarily reflects the $\delta^{18}O$ of local lake water. Thus changes in the $\delta^{18}O$ of ostracode carbonate in a core should directly reflect changes in the $\delta^{18}O$ of the water in which the animals grew.

The oxygen isotope ratio of different sources of water in the delta environment of Lake Tanganyika is quite variable. Open lake water ranges from +4.2 per mil (SMOW) in deep water to a value of +3.5 per mil (SMOW) at the surface; samples collected from nine rivers in 1973 ranged from +1.2 to -3.8 per mil (Craig et al., 1974). Thus all runoff entering the lake is more negative than the lake water and variation in the mixing ratio of river and lake water in a delta may be recorded as $\delta^{18}O$ variation in carbonates precipitated on the delta. Ostracode carbonate precipitated under open lake surface conditions (24 to 27°C, 3.5 per mil SMOW) is expected to be +2.65 per mil PDB, based on a +1 per mil offset from the expected inorganic calcite value (Friedmann and O'Neil, 1977). No $\delta^{18}O$ data exist for the rivers associated with these cores, but runoff amount estimates can be crudely quantified using an average small river $\delta^{18}O$ value of -3.3 per mil SMOW (Craig *et al*., 1974). A linear mixing relationship between the two end members (+3.5 and -3.3) can be used to estimate changes in runoff percent at a point on a delta. Based on these end-members, a 0.1 per mil change is about a 1.5% change in the amount of river water at that location.

Core 2M, from the Lubulungu Delta, shows a slight trend in $\delta^{18}O$ toward more positive values higher in the core (Fig. 3.27a). This implies that runoff percentages decreased at this location over the first half of this millennium. The uppermost sample of the core, perhaps representing modern conditions, indicates a return to a greater amount of runoff, similar to that of our lowest sample. The most positive values of ostracode seen here (+2.5 per mil) is close to a pure lake water $\delta^{18}O$ signal. The decrease of 0.46 per mil in valves may reflect an increase of about 7% in the amount of river water at that location.

Core 18M, from the Kabesi Delta, has a trend toward more negative values toward the top of the core. This probably reflects an increase in runoff amount over the last half century at the core location. The most positive $\delta^{18}O$ value in core 18 is very similar to the most negative of core 2m, implying that there is significant river water present at the core location when the isotope record begins at 19cm. Beginning from a river water percentage of approximately 7% the decrease from +2.15 to +1.7 can be modeled as an increase to 14% river water at the core location.

In three samples from Core 37m at 43-44cm we attempted to get a direct comparison of the environmental preferences of three species. Unfortunately the *Romecytheridea* sp. 13 sample was lost due to small sample size. The other two samples show a large difference in both $\delta^{18}O$ and $\delta^{13}C$. *Mecynocypria opaca* has a $\delta^{18}O$ value of -2.71 per mil, similar to the open lake end-member of +2.65 for calcite. The $\delta^{13}C$ is much more positive than either of the other species measured in this study. This implies that it derives more of the carbon in its shell from dissolved inorganic carbon (DIC) of the water column. The other species probably make more use of organic carbon in the construction of their shell carbonate or live in environments semi-isolated from the lake DIC. Finally the one sample of *Gomphocythere* n.sp. "downingi" shells has an intermediate $\delta^{18}O$ value, suggesting the presence of significant amounts of river water when compared to the co-existing *M. opaca* shells.

Chapter 4. Discussion

Each core investigated in this study revealed a unique history of watershed and lake ecology change. Therefore we will synthesize our findings by locality first, then by comparisons between sites.

4.1 Core 2M-Lubulungu River-W. Mahale Mountains

This core provides us with our longest-duration record, extending back to the mid-Holocene. Although it was not our original intention to investigate deltaic records prior to the last few hundred years, the results from this core are nonetheless interesting because they provide information on landscape variability in the Mahale region long prior to the modern situation.

Core 2M is characterized by extremely slow sedimentation rates overall, although those rates change markedly upcore. At about 700B.C. sedimentation at the core site shifted abruptly to finer muds. This initial fining was associated with increasing total organic and inorganic carbon input. About 100AD charcoal content in the core begins to rise appreciably and benthic detritivores (ostracodes and gastropods) make their initial appearance in the record. Siliciclastic sand input was completely eliminated by about 400-500AD, by which time sedimentation at the core site was completely comprised of fines. This habitat conversion, apparently advantageous for the detritivore food web, also corresponds with the near disappearance of sponges, perhaps in response to excessive siltation. Secondary major increases in charcoal flux after the 1300s-1400s AD are contemporaneous with declines in ostracode diversity.

Increased fire activity associated with watershed conversion from woodland to grassland cover may be the agent ultimately responsible for the change in sediment discharge. This was eventually reflected in textural changes, sedimentation rate changes and community changes (increased detritivores at the expense of filter feeders). However the various changes are not simultaneous, not surprising given the offshore position of the coring site and the probable lag times required for watershed changes to make themselves felt in the lake. It is difficult to state with any certainty whether these changes resulted fundamentally from human activity, climate change, or some combination of the two. However several lines of evidence suggest that climate change is the more likely dominant factor, and that this change is fundamentally different from the more recent changes observed in other cores. First, the magnitude of sediment inundation and its associated ecological impact is far less than that observed in the highly disturbed and deeply eroded Burundian watersheds. This may imply that although the landscape of the western Mahale Mountains was converting to one in which seasonally burning grasslands were increasingly common (perhaps intentionally burned?), this change was not accompanied by the deep erosion typical of agriculturally disturbed soils. Certainly the slopes are adequate in this area to yield large quantities of sediment to the lake had this occurred. Second, the replacement of arboreal by grass pollen is not accompanied by any evident change in pteridophyte spore proportions, a hallmark feature of the reverse grass to tree pollen-dominated proportional changes seen in the other cores in the past few centuries (with the notable exception of core 12M, which, as discussed below may be more similar to core 2 in its clearer reflection of land cover by pollen type proportions). Third, the decline of woodlands and increase in grasslands is a general phenomenon of eastern Africa over the past 3000 years, including in Madagascar, where human occupation only dates to about 1000 AD (Vincens, 1989, 1991, 1993, Livingstone, pers. comm., 1999). Ostracode diversity **does** decline after the 1300s-1400s (simultaneous with the major increase in charcoal), so erosion may have exceeded the threshold at which detritivores start to be negatively impacted by siltation, but the decline is small compared with our observations from other more recently disturbed sites.

4.2 Core 12M-Lubulungu River-W. Mahale Mountains

This core records the history of the western Mahales and its lake margin over the past ~6 centuries, and thus only partly overlaps with the 2M record. It is important to bear in mind however, that the chronology of core 12M is weaker than that of any other core. The fact that these two core sites (2M and 12M) lie so close to one another and yet cover such different time intervals and accumulated sediment at such different rates (2M is on a distal, possibly inactive lobe, whereas 12M is on the downslope path of more recent sediment transport) highlights the need for caution in drawing overly broad interpretations about the history of an area from a single deltaic site core. The Lubulungu delta at least shows clear evidence for spatial heterogeneity in terms of depositional processes and it is reasonable to generalize this dynamism to other L. Tanganyika deltas as well.

The overlapping portions of cores 2M and 12M probably date from the 15th century and are generally coherent with one another. Both show relatively high charcoal levels suggestive of heightened fire activity at that time, which declined by some time in the 16th to 17th century to much lower levels.

Major changes in core 12M date from the mid 19th century. Increasing charcoal flux, decreasing grass pollen, increasing ostracode, mollusc and fish abundance (the latter two declining precipitously after this increase), and a slight coarsening of sediments all date from this period. Interestingly these changes are not accompanied by any change in TOC. An explanation of this curious grouping of changes probably requires multiple causes. Charcoal and palynological data are consistent with the hypothesis of regional landscape conversion to intensive subsistence agriculture discussed earlier. However this model would require that these records are not solely reflecting the local Lubulungu watershed, given the very low human population density and heavy forest and woodland cover existing in the area today. Such a model would argue that both the pollen and charcoal signals must be inherited from an extremely large area, given the lack of any major settlement within ~50km of this site.

An alternative hypothesis is that increase in arboreal pollen (evident after the early 20th century) and decreasing grass pollen reflect the actual progressive reforestation of this region after the 0-1000AD decline (recorded in 2M). As with core 2M it is difficult to separate possible climatic vs. anthropogenic explanations of such a change. Fire was clearly a common phenomenon of the 15th century in this area and shows signs of decline (16th-19th century) and then subsequent increase in the region, but whether these were intentionally set or caused by drier conditions is difficult to determine based on our available evidence. Vast fire burns are known from forested parts of this region today (they are easily visible from the ground and in satellite imagery, and most appear to ignite during the long dry seasons). The numerous high elevation areas of the Mahale Mountains that are currently barren of trees (not above thermal tree line) also points to earlier extensive burns. Dramatic increases in charcoal at the top of core 12M, coupled with evidence for increased arboreal pollen are not easily reconciled with increased agricultural pressure in the Lubulungu River valley during the 20th century, given the existing heavy forest cover of this region today.

Patterns of benthic organism change during the 19th and 20th century are not easily explained by any of the above models, and suggest that they are largely unrelated phenomena. Our admittedly weak age model suggests that increases in benthic detritivore (though curiously not filter feeding sponges) and fish fossil flux both increased at a time (1850s-1870s) of increasing and generally high lake levels, when this currently dysaerobic site (126m current water depth) would have been even deeper and less hospitable in terms of oxygen availability (~140m, based on historic records). This increased water depth must have been offset by greatly increased wind generated mixing of surface waters (or substantially cooler water temperatures to allow the same).

4.3 Core 18M-Kabesi River-N. Mahale Mountains

This core provides a record of change along the northern side of the Mahale Mountains and adjacent offshore areas over the past 250 years. An excellent age model is available for this core, and the core shows coherent and interpretable patterns of change, particularly over the past century. Palynologic records show the previously discussed decline in grass pollen and increase in arboreal types and ferns. The transition begins in the late 19th century and accelerates greatly after 1961. These same time intervals of change show up in many records from core 18. Ostracode abundance starts to increase in the late 19th century and increases rapidly after 1961, as do sponges. The ostracode record change involves a major decline in diversity and an increase in assemblage dominance by well-preserved juveniles of *Romecytheridea* sp. 13, a relatively shallow water, muddy bottom species. Although sedimentation rates do not show any significant change in the late 19th century, they triple in 1961. Increasing sedimentation rates at that time suggest that both TOC and TIC must have increased in terms of flux to maintain their constant proportionality.

The 1961 increase in sedimentation rates, TOC and TIC flux, increase in *Romecytheridea* sp. 13 ostracodes, sponge spicules (presumably derived from shallow water), stable isotope records and coarse sediment input all point to a major increase in the efficiency with which shallow water sediment (both in suspended and bed load) was being transported offshore to the core site. There are at least two reasons why such increased transport might have occurred. Either total discharge (water plus sediment) increased or the position of the predominant distributary channel outlet changed, making the core site much more proximal to it. Earthen-work drainage diversions for irrigation purposes can be observed on the lower Kabesi and new outlet channels are constructed periodically. However interviews with local residents suggested that such features were constructed more recently than the early 1960s.

The correspondence of the lake signals with the palynologic record, as well as our rough hydrologic modelling from stable isotope data provides strong support for a total discharge explanation. A well known consequence of decreased forest and woodland cover is increased hydrologic discharge, as overland impediments to flow are removed from the landscape. Early indications of this change may date from the late 19th century, when palynologic changes first appear and benthic detritivores first start to increase in abundance. But clearly the big change dates from the early 1960s.

4.4 Core 58M- Nyasanga/Kahama Rivers-Gombe Area

Core 58M, collected in 76m of water, records a ~300 year history adjacent to Gombe Stream National Park. Terrestrial indicators show the previously-discussed grass-arboreal pollen conversion starting in the 18th Century and accelerating in the mid 20th century. Extremely abundant charcoal occurs throughout the core, with the highest values both in 18th century sediments and again in the mid-late 20th century. In contrast to these indications of terrestrial disturbance there is no indication of concurrent sedimentologic change, most notably in the absence of increasing sediment accumulation rates. Coarse sediment input, TOC and TIC all show slight increases in the late 19th century, and correlate with changes in ostracode productivity, but the timing of these changes seems unrelated to the terrestrial signals, and benthic invertebrate diversity is very high throughout this core. It seems probable that the pollen and charcoal record the regional pattern of changing land use in northern Tanzania (and perhaps southern Burundi, given the evidence for long-distance pollen transport) during the 19th-20th centuries, rather than providing a watershed scale signal (although see discussion of core 37 below for another alternative). This is perhaps not surprising, given the small size of the Nyasanga/Kahama drainages. The only terrestrial indicators which might possibly be attributable to local (i.e. within Gombe Park) changes following the gazetting of the park is the apparent increase in woodland tree pollen which dates from this time. Possible evidence for this comes from the records of *Brachystegia* and *Acacia*, which occur in the park today as mid-elevation (1200-1400m) large trees and low elevation (775-950m) thickets respectively (Clutton-Brock and Gillett, 1979). No evidence exists from the pollen records to document extremely recent conversion of low elevation woodland to canopy forest that has been observed in recent decades in the protected park areas (A. Collins, pers. comm., 1999).

4.5 Core 37M- Mwamgongo River-Gombe Area

This core, collected in 95m water depth, provides a ~500 year record of a region that for most of its history was probably quite similar to the 58 core Nyasanga/Kahama area. Contrasts between the two sites are therefore of considerable interest (Nyasanga/Kahama having been afforested starting in the 1950s and Mwamgongo having continued to be a site of ever denser human settlement over the same time).

At first inspection core 37M presents a confusing and seemingly contradictory array of indicators of change. Sedimentation rate increases substantially in the early 19th century (accompanied by a notable fining of grain size), but not noticeably in the mid-late 20th century. However the nature of sedimentation in the mid 20th century does change, both in appearance and composition. The abrupt near-top switch to reddish brown clays, reminiscent of eroded lateritic soils and seen in multiple unanalyzed cores from this delta, coupled with the abrupt decline in TIC (from a condition of previously very high carbonate input) both suggest terrestrial forcing of sedimentologic changes.

Terrestrial signals confound this picture further. Although the long-term decline in grass pollen, and increases in arboreal pollen and pteridophyte spores are evident in this core, the uppermost 6cm (where the sedimentologic changes occur) show a decline in tree pollen (though pteridophytes increase markedly). If land use conversion was increasing the proportion of species other than grasses in this area, for some reason it must have been resulting in a disproportionate increase in ferns and a relative decrease in tree species.

The absence of a mid 20th century increase in sedimentation rates at this site may be attributable to two likely causes. First, sediment yield from the small Mwamgongo watershed may simply be insufficient to generate substantially higher rates of accumulation. On steep escarpment margins of Lake Tanganyika, like this area, the proportion of alternative sources of sediment other than deltaic siliciclastics is often high (note the exceptional TIC content of this core). Short term storage of sediment on depositional benches like the core site may also be self limiting, given the overall steep nature of this coastline. Sediment may simply be regularly sloughed off into much deeper water as slope angle increases. Such a model of periodic sedimentation and reworking would help to explain several other surprising observations. First, there is a notable increase in the shallow water ostracode disturbance indicator *Romecytheridea* sp. 13 in the upper part of this core (the absolute percentages are low, but this is unsurprising given the limited amount of shallow water muddy habitat). Also, ostracode diversity remains high through this upper interval. This may indicate that overall community disturbance is regulated or dampened by the combination of small watershed area and steep slopes prevailing in the Mwamgongo area.

One remarkable observation which we cannot fit into any simple depositional model for the upper part of core 37M is the absence of any increase in charcoal comparable to 58M. If charcoal flux is truly a regional phenomenon, as we have argued previously, then where is this signal? Perhaps we are misinterpreting the significance of the high levels of charcoal in core 58M (we have no record of whether there were exceptional fires within the Gombe Park area in recent years, although it seems likely that the Park staff would have such information). Alternatively it is possible that charcoal deposition in Lake Tanganyika is focussed by local limnologic conditions (headland barriers to circulation, descending currents etc.) for which we have no information.

4.6 Core 98A/M- Nyamuseni River-N. Burundi Area

Core 98, collected in 61m water depth, represents a brief record of environmental change, covering only the past 40-50 years. Sedimentation at this site has been characterized by very rapid and increasing accumulation rates. Based on the shape of the ^{210}Pb profile, sedimentation also appears to have been pulsed or episodic at this site, and may in fact involve a series of large rapid events, each leaving several cm per year. Based on the combination of ^{210}Pb and ultramodern ^{14}C dating sedimentation rates average ~1cm yr^{-1}, although there is strong evidence that this rate has accelerated on the order of a doubling per 22yr (^{210}Pb half-life). The ^{210}Pb profile, coupled with the ^{14}C age control, suggests that this period of rapid acceleration dates to the early 1960s (note major inflection in ^{210}Pb profile at ~30cm, transitioning to an interval of a near-vertical profile, indicative of very rapid rate increase), similar to our results elsewhere.

Palynologic data shows few trends over the brief core interval (1950s-1990s), perhaps not surprising given the long history of dense population pressure in the area (e.g. compare with core 82M). Some upcore increase in pteridophyte spores is evident, along with a slight decline in grasses but these are probably statistically insignificant.

The core is also characterized by its very low TIC content (and absence of shelly fossil material, except at the core top). The core top and near core top occurrences may represent a recent recolonization of the site. This may occur periodically between sediment pulses (brief turbidity or debris flows which subsequently remove the local shell assemblage downslope) or may represent unique conditions for the past 50 years.

Associated with the abrupt appearance of benthic fauna is a rapid decline of charcoal input during the mid 1990s. Given the heavy population density in this area this result was surprising. It is possible that civil unrest in Burundi in the mid 1990s resulted in abandonment of subsistence farms in the area (and subsequent reduction in cooking fire activity by the local population), and this may be testable from Burundian government records of the area. It is possible that the charcoal reduction and benthic faunal increases are linked, though more data would be required to test this hypothesis.

4.7 Core 82M- Karonge/Kirasa Rivers- N. Burundi Area

Core 82M, collected in 96m water depth, covers an interval of about 250-300 years. Although the coring site lies offshore from the combined Karonge/Kirasa river delta, both the bathymetric profiling and some palynologic evidence (presence of *Acacia* pollen, uncommon in the local watershed but abundant in the Ruzizi River plain) suggests an input of Ruzizi River sediment to this site. Much of the core is laminated, and laminated sediment frequency increases upcore. The coring site lies within the currently oxygenated zone of the lake in this area. However earlier ROV studies off the Karonge River mouth have shown that laminated sediments are accumulating in oxygenated waters where sedimentation rates are too high to allow bioturbation to efficiently remix the sediment mass. In fact the ^{210}Pb profile from the 82M core shows a remarkable record of 10-fold increasing sedimentation rates (consistent with the earlier work by Wells et al. (1999) for this same area) over the core interval. The increase in accumulation rates was underway by the late 18th or early 19th century (prior to which rates were comparable to the "average" lake-wide deltaic values we have observed of ~1mm yr^{-1}, but a major acceleration of that trend is evident from 1961.

Sedimentological indicators show that an upcore decrease in coarse grained sediment sets in during the early-mid 19th century. TOC remains relatively constant through the core whereas TIC is low and shows declining values. However these are largely dilution effects: when normalized for flux, both TOC and TIC input per unit time must be increasing substantially through the core interval, possibly the result of rising primary productivity.

Charcoal trends are surprising in light of the results from nearby core 98. Low concentrations of charcoal occur through most of the core, with a decline after the mid 19th century and then with a slight increase in proportion near the top of the core. These translate into a similar flux record, except that charcoal input in the 1990s must be substantially higher given the rapidly accelerating sedimentation rates near the core top. The dramatic difference of this results from the 98 core top argues for caution in interpreting these charcoal records, as differential sedimentation processes may be at work. A systematic investigation of land use practices in the Nyamuseni vs Karonge/Kirasa drainages during the 1980s-1990s would be enormously helpful in making sense of these results.

The long-term trend of decreasing grass pollen, increasing arboreal pollen and increasing pteridophyte spores is evident in core 82. Like the sedimentation rate data and pollen records from other cores, the 82 core pollen data makes clear that this is not strictly a 20th century phenomenon. The generally higher proportion of montane tree pollen near the top of core 82 relative to 98 may reflect the fact that the upper parts of this combined watershed (in particular, the upper Kirasa basin) still has residual patches of forest area along water courses, whereas such patches have largely been eliminated from the Nyamuseni basin. There is good evidence in the 82 core for the late 1920s/1930s introduction and expansion of *Eucalyptus* (non-native Myrtaceae) and the timing of that expansion is consistent with what is known from historic records of *Eucalyptus* introduction.

The disappearance of ostracode, fish and mollusc fossils from the record in the early-mid 19th century is notable, since it is consistent with earlier hypotheses that reductions in ostracode, fish and molluscs in Burundian waters are not strictly 20th century phenomena. The ostracode species present prior to the disappearance are dominated by high sedimentation rate-tolerant taxa. Taphonomic indications in the fossils at the base of the core suggest that even this assemblage may be made up of reworked fossils and was not a life assemblage representative of conditions at the time of deposition. The most peculiar and inexplicable record in the 82 core is the upcore increase in sponge spicule abundance. Given the strong indications for increasing sedimentation rates through this time period (last 150 years) it is hard to understand why filter feeder abundance is systematically increasing, especially since sponges are known from many contexts to be intolerant of sediment fouling. The finding suggests that reworking of sponge spicules (perhaps from shallow water areas through more vigorous flood flow, as was hypothesized for core 18) rather than local abundance, is the key to interpreting sponge fossil occurrence in Lake Tanganyika.

4.8 Comparisons Between Coring Sites And Regions

Several notable trends can be observed in our paleolimnologic data that may be interpreted on a regional basis. These trends have implications for a variety of watersheds entering Lake Tanganyika, for the linkages between land and lake processes affecting the lake's ecology, and for levels of threats to the lake ecosystems based on watershed characteristics.

Palynologic profiles and charcoal analyses both provide us with evidence of the histories of our study watersheds. However the interpretation of these histories is clouded by the varied transport phenomena that affect both pollen and charcoal, especially the fact that both may be carried to our core sites from areas outside of the watersheds. This is an inevitable "messy" part of interpreting this type of data, and argues strongly for more modern analog studies (watershed scale vegetation mapping, repeat photography and modern pollen rain collections) to help calibrate the core data.

Core 2M, our longest record, provides evidence for a decline in forest cover over the past 3000 yr., accompanied by various lake responses. The shift in vegetation cover and lake response is particularly strong from ~100-1300AD, and corresponds with similarly-timed records elsewhere in Africa, even in areas that were not colonized by humans. Thus, the evidence points to this change as being dominantly (though perhaps not exclusively) driven by climate change, towards a drier regime that encouraged the growth of fewer trees and the occurrence of more fires. The fact that climatically and anthropogenically-driven changes in land cover can proceed in similar directions cautions us in not trying to over-interpret the existing data as to cause and effect, particularly with regard to "downstream" linkages to lake ecology. However it is important to note that several of our indicators (e.g. the meaning of pteridophyte abundance patterns) suggest there may be some key (perhaps fundamental) differences between the patterns of deforestation driven by climate events vs. agricultural land use, and these need to be more fully explored. Again these will require modern analog studies not available to us at the time of this report.

Widespread palynologic trends towards increased arboreal pollen and pteridophyte spores and decreased grass pollen are perhaps the most surprising results to come out of our study. They highlight the need to understand what controls the modern pollen rain in mixed agricultural forested systems in Africa, where cultivated plants are poor pollen producers. Our explanation of the increase in arboreal pollen as a response to a lowland conversion of progressively more land out of pollen production is admittedly *ad hoc* and may be proven wrong. But no other "literal" interpretation of these trends (i.e. that pollen percentages correspond with percentages of plants in the watersheds) seem to accord with known facts about the modern condition or the contrasts between modern watersheds. Again we will need to sample pollen rain, or revisit the core samples with new pollen counting procedures that would allow us to accurately estimate pollen flux in order to clarify this problem.

Increased sediment accumulation rates are evident in a number of cores we have studied. All core sites showing such trends are in localities exhibiting either moderate or severe levels of deforestation. However not all deforested watershed cores show this pattern, notably core 37 (Mwamgongo). The very small area of this watershed argues that a drainage basin size threshold is important in considering threats to adjacent lake communities. Particularly in the more northerly (and heavily populated) regions, evidence of accelerated sediment accumulation rates occurs both prior to and during the 20th century. However a major increase is evident from multiple, unrelated localities at or about 1961.

The remarkable coincidence of increasing sediment accumulation rates dating from ~1961 requires explanation. Two hypotheses can be forwarded for this based on the timing. First, it is possible that some regional change in land use patterns occurred at that time, perhaps associated with the end of colonial rule, which dates approximately from this era. This explanation seems unlikely to us, since there are no historical records of such a change occurring, and since the land use and tenure systems varied considerably between Tanzania and Burundi (the pattern is observed in cores from both countries).

A more likely explanation of the pattern involves a combination of climatic and anthropogenic causes. 1961 was a record wet year in East Africa, with high water levels recorded in almost all lakes and gauging stations (S. Nicholson, pers. comm. 1999). Although the sustained mid 20th century increase in sedimentation rates is ultimately a likely consequence of increased erosion rates on cleared farm land, it is uncertain how efficiently or quickly this sediment is delivered to Lake Tanganyika. Much of it may go into temporary alluvial storage in river valleys, requiring a "triggering mechanism" to stimulate its delivery to the lake. Extraordinary rainfall events are known to have such effects on alluvium, incising head cuts in soft alluvial sediments that propagate themselves upstream after the initial incisions are made. We believe a combination of anthropogenic and climate forcing is the most likely explanation for the coincidence of this timing of accelerated sedimentation rates.

Interpreting the ecological response to inferred watershed changes within Lake Tanganyika is central to our goals in this project. Our results show that high diversity ostracode assemblages are associated with low disturbance areas and that low diversity assemblages (or in some cases a complete absence of benthic organisms) are associated with the highest levels of disturbance. Furthermore there are clear associations of particular taxa with high disturbance levels, and these species can be shown to become more dominant under increasingly disturbed (i.e. more rapidly sedimented) conditions. At intermediate levels of disturbance however the responses are more complex. It seems that thresholds of disturbance may exist. At low levels of fine particulate input an increase in suspended sediment load appears to stimulate benthic detritivore productivity and diversity. This may have occurred as a result of the prehistoric deforestation event recorded in the western Mahale Mountains (core 2M). Also moderately high levels of watershed disturbance may not translate into signs of community disturbance if the watersheds are very small or if the sublacustrine slopes are very steep. In either case (or, as in the Mwamgongo situation, where both are operational) short-term sediment accumulation may be limited by either total supply or the short term nature of the storage. Although it is clear from the work of O'Reilly (1998) and others that the Mwamgongo shallow lacustrine communities are qualitatively different from those of nearby areas inside of Gombe Stream National Park, it is less clear that these littoral impacts translate into major effects in deeper water downslope (at our coring sites).

Our data illustrate that for many of the watersheds surrounding northern Lake Tanganyika, change in vegetational cover and lake system response has been undergoing systematic change for at least several centuries. It is not a strictly 20th century phenomenon, although it is undeniable that a major acceleration of change (particularly notable in gross sediment accumulation rate) has occurred since the middle of the 20th century. Our data also suggest that there may be predictable levels of linkage between landscape disturbance and lake ecological response. The northern Burundian coastline has probably been particularly susceptible to sedimentation-generated disturbance because it experiences two aggravating factors. First watersheds are relatively large, and thus capable of delivering large quantities of sediment to what are effectively point source outlets (delta distributary discharge points), even if no disturbance were occurring. Second, underwater slopes along the Burundi coast are relatively gentle, encouraging short term storage and accumulation. If the Ruzizi has been a long term contributor to the sediment budget of the northeast part of the lake, it is predictable that this slope factor would become more aggravated as one moves further north in this region, whereas the watershed area factor would be more variable. If this hypothesis of enhanced vulnerability is correct, then particular attention should be paid to geomorphically similar parts of the lake basin which have not yet experienced such pervasive settlement and cultivation, particularly at the south end of the lake and on the major platform regions (South Malagarasi, in the Halembe area and the Ikola Platform). Mitigating problems associated with accelerated erosion in such areas if they become highly disturbed in the future will be a daunting challenge.

Conversely, the threats to lake systems are probably reduced in areas of steep slopes and small watersheds. Places like the Mwamgongo watershed are unlikely to generate the quantities of sediment required to impact large areas and enhancement of sediment storage in the sublittoral zones may be relatively subdued or nonexistent. Clearly threats will exist in such areas to the littoral zones most directly adjacent to the river discharge point when erosion rates accelerate. However these problems must be placed in context with the far more serious threats posed by disturbance in the more vulnerable large watersheds and gently sloping regions of the lake.

Chapter 5. Recommendations

As with many hybrid scientific/management investigations, our results raise many more questions than they can answer. In part this is a result of the limited amount of information that can be drawn from a single core in a complex depositional system like a delta, and in part it results from our limited knowledge base concerning modern processes in Lake Tanganyika and its watershed from which we can draw solid interpretations. Our recommendations largely, though not exclusively, go towards redressing these problems.

5.1 Detailed Analysis Of Target Deltas

5.1.1 Core and sedimentological analysis

We strongly recommend that the GEF project consider providing funds to accomplish Phase II of the University of Arizona's original project proposal. This would entail further analysis of existing cores within one or two deltas. Work would concentrate on obtaining within-delta comparisons of sediment accumulation rates at various proximal to distal localities, to allow us to develop a Gilberto model of sediment accumulation and to integrate our work with the LTBP hydrologic modelling and sediment discharge data sets. Without knowledge of the geometry of the sediment blanket being deposited on a delta it is impossible to relate sediment erosion and stream mouth discharge rates (e.g. flux in tons yr^{-1}) to sediment accumulation rates, because fluxes derived from a single core locality on a delta (what we have now) are unlikely to be representative of the delta as a whole, and because we cannot determine the area over which the sediment blanket is accumulating from a single core. To accomplish this we would concentrate on obtaining ^{210}Pb profiles and additional ^{14}C data from a series of locations on one or two deltas that combine good core coverage with available hydrologic data and watershed models.

We do not recommend further coring operations in Lake Tanganyika. Between our 1997 and 1998 field campaigns we are now in possession of almost 200 cores from the lake, far more than all previous coring expeditions combined. The only coring which might be useful at this point would be the collection of short cores in some marginal lakes with small catchment areas, to address some of the taphonomic problems of interpreting the palynological history discussed earlier.

5.1.2 Geochemical Tracers ($^{147}Sm/^{144}Nd$) Of Deltaic Sediment Provenance

One of the more intriguing findings from our study is the suggestion from field observations as well as sedimentologic and palynologic data that sediment input from the Ruzizi River is transported by coastal currents southeast along and across the northern Burundi coastline deltas. If the Ruzizi is an important sediment source along the northeastern Burundi coast, it will have profound management implications for mitigating sediment loading in this region, since local solutions to erosion in the mountainous areas of western Burundi would only redress part of the problem. Interpreting both the reality and the magnitude of such a source requires some form of tracer that can both distinguish Ruzizi from local sediment sources and that is likely to be transported in equal proportions to the suspended sediment load (our dominant concern). Fortunately, such a tracer may exist. In collaboration with Jonathan Patchett, a geochemist at the University of Arizona, we have made some preliminary measurements of $^{147}Sm/^{144}Nd$ in suspended sediment samples collected during the dry season from the Ruzizi and Karonge Rivers. $^{147}Sm/^{144}Nd$ is a function of the age of fractionation of crustal rocks and the ratio provides a model "age date" that describes the average age of the components making up these isotopes (Patchett, 1992). In a mixed suspended sediment sample such as we have analyzed, the ratio integrates the model ages of all eroded rocks in the catchment. Our preliminary results show that there is a substantial difference in the expected model ages of sediments derived from the Ruzizi vs. the Karonge River watersheds. The Karonge River bedrock is entirely composed of Middle Proterozoic metamorphic rocks, whereas the Ruzizi River watershed bedrock is a ~75:25 mix of Middle Proterozoic rocks and Late Tertiary volcanic rocks. This difference would imply that $^{147}Sm/^{144}Nd$ model ages for suspended sediments from the Ruzizi River should be substantially younger than those of the Karonge. In an initial pair of analyses this is in fact what we have found. The Karonge sample yielded a model *T(DM)* age of 1937Ma and a *T(ChUR)* age of 1622Ma (consistent with the mid-Proterozoic origins of these rocks), whereas the Ruzizi sample yielded *T(DM)* =1466Ma and *T(ChUR)* =1038Ma (consistent with a mixture of Proterozoic and Late Tertiary rocks). We are now trying to duplicate these results with additional wet season samples from the same two rivers (there may be significant seasonal differences in the source of water and sediment) and from the Kirasa River (to determine variability between rivers that are 100% Proterozoic bedrock). If these results confirm our initial findings we would like to analyze the Karonge core 82M to determine the $^{147}Sm/^{144}Nd$, thereby producing a relative flux calculation from the two river sources. We would do this at several points along the core to see if the ratio changes with time (i.e. has the Ruzizi influence as a sediment source along the northern Burundi coast changed systematically over time).

5.2 Botanical Surveys Of Target Catchments

In the absence of detailed botanical information on the study watersheds it is difficult for us to fully utilize our palynologic data. This could incorporate existing or ongoing remote sensing surveys, coupled with ground-truthing of major vegetation types in selected areas. Surficial pollen and spore samples should be collected routinely as part of this exercise, across both land use gradients and altitudinal gradients. Interpretation of pteridophyte spores seems a likely lynchpin for such an exercise and efforts should be made to ensure that identification of pteridophytes to lower taxonomic levels is possible and that such identifications can be linked to ecologic information. If additional palynologic work is to be done on existing cores or marginal lake cores, effort should be made to ensure that appropriate spikes are available to determine fluxes (i.e. using species that do not occur in the Tanganyika region).

Useful historical data probably exists in the form of photographic archives (especially where repeat photography might be available), or colonial or early post-independence agricultural records, that could greatly augment our efforts. National archives frequently store such information. Although such data would have certainly been collected for purposes other than what we intend, a careful analysis of such available records could pay off greatly, since we know that many of our cores document the historic period in great detail.

5.3 Further Gradient Analysis Of Lake Sediment Flux And Benthic Organism Distribution/Taphonomy

Probable reworking of charcoal, ostracodes and sponges all pose serious challenges to making useful interpretations. In fact this taphonomic concern should not be viewed as a negative, *information loss* type of variable. Both the processes of transport and deposition for any of these indicators may become factors of interest in their own right if they are linked to ecologically significant events in the history of watershed disturbance. Surficial sediment analysis of charcoal abundance and target ostracode species across one or two of the best studied deltas could be extremely beneficial in furthering our aims of accurate interpretation. Sponge spicules might be identifiable to species given some investigative effort and this, coupled with systematic surface sediment sampling and more detailed ecological survey information may help sort out the confusing patterns observed in the spicule counts.

References Cited

Alin, S. R., A. S. Cohen; R. Bills; M. M. Gashagaza, E. Michel; J. J. Tiercelin; K. Martens; P. Coveliers; S. K. Mboko; K. West; M. Soreghan; S. Kimbadi and G. Ntakimazi. (1999, in press). Effects of landscape disturbance on animal communities in Lake Tanganyika. *Conservation Biology*.

Bengtsson, L. and M. Enell. 1986. Chemical analysis, Chapter 21. In: Berglund, B. E. (Ed.). Handbook of Holocene palaeoecology and palaeohydrology. John Wiley and Sons, Chichester, pp. 423-451.

Bizimana, M. and Douchafour, H., 1991, A drainage basin management study: The case of the Ntihangwa River Basin. p. 43-45, in Cohen, A.S. (ed.) Report of the First International Conference on Conservation and Biodiversity of Lake Tanganyika. Biodiversity Support Program, Washington ,D.C., 128pp.

Bygott, D. 1992. Gombe Stream National Park. Tanzania National Parks & African Wildlife Foundation, 71 pp.

Clutton-Brock, T.H. and Gillett, J.B., 1979. A survey of forest composition in the Gombe National Park, Tanzania. Afr. Jour. Ecol. 17:131-158.

Cohen, A.S., 1989. The taphonomy of gastropod shell accumulations in large lakes: an example from Lake Tanganyika, Africa. Paleobiology 15:26-45.

Cohen, A.S., Bills, R., Cocquyt, C. and Caljon, A.G., 1993, The impact of sediment pollution on biodiversity in Lake Tanganyika. Conservation Biology 7:667-677.

Cohen, A.S., L. Kaufman and R. Otugu-Ohwayo. 1995. Anthropogenic threats, impacts and conservation strategies in the African Great Lakes - A review. In: T.C. Johnson and E.O. Odada (Eds.). The limnology, climatology and paleoclimatology of the East African Lakes. Gordon and Breach Publishers, Newark, New Jersey: 575-624.

Cohen, A.S., Talbot, M.R., Awramik, S.M., Dettman, D.L., and Abell, P. 1997, Lake level and paleoenvironmental history of Lake Tanganyika, Africa, as inferred from late Holocene and modern stromatolites. Geol. Soc. Amer. Bull. 109:444-460.

Cohen, A.S. *in press*, Linking spatial and temporal changes in the diversity structure of ancient lakes: Examples from the ostracod ecology and paleoecology of Lake Tanganyika. *in* Rossiter, A. and Kawanabe, H. (eds.) Biology of Ancient Lakes. Kyoto Univ. Press., 24pp. ms.

Coulter, G. W. 1991. Lake Tanganyika and its life. Oxford University Press, Oxford, United Kingdom, 354 pp.

Coulter, G.W. and R. Mubamba. 1993. Conservation in Lake Tanganyika, with special reference to underwater parks. *Conservation Biology*, **7**: 678-685.

Craig, H., Dixon, F., Craig, V., Edmond, J., and Coulter, G. 1974. Lake Tanganyika geochemical and hydrographic study: 1973 expedition. *Publication of Scripps Institution of Oceanography 75*. 1-83.

DeBusk, G.H., 1997. The distribution of pollen in the surface sediments of Lake Malawi, Africa, and the transport of pollen in large lakes. *Rev. Paleobotany & Palynology* 97:123-153.

DeBusk, G.H., 1998. A 37,000 year pollen record from Lake Malawi and implications for the biogeography of afromontane forest. *Jour. Biogeography* 25:479-500.

Dettman, D. L., A. J. Smith, D. K. Rea, K. C Lohmann and T. C. Moore Jr. 1995a. Glacial melt-water in Lake Huron during early post-glacial times as inferred from single-valve analysis of oxygen isotopes in ostracodes. *Quaternary Research*. 43:297-310.

Dettman, D. L., A. S. Cohen, T. M. Wells, M. R. Talbot, P. Abell, B. A. McKee. 1995b. Isotopic records from the last 1000 years in Lake Tanganyika, implications for the paleo-environmental interpretation of carbonates in cores from the African rift lakes. Abstract, *Geological Society of America Annual Meeting.*

Forester, R. M. 1991. Ostracode assemblages from springs in the western United States: implications for paleohydrology. *Mem. ent. Society of Canada*, **155**, 181-201.

Friedman I. and O'Neil J. R. 1977. Compilation of stable isotope fractionation factors of geochemical interest. *U.S.G.S. Professional Paper* 440-KK.

Gasse, F., Massault, Ledee, E.V., Massault, M. and Fontes, J.-C., 1989. Water level fluctuations of Lake Tanganyika in phase with oceanic changes during the last glaciation and deglaciation. *Nature* 342:57-59.

Gereau, R., Mbago, F.M., Kayombo, C. and Collins, D.A. (in press). Annotated checklist of vegetation of Gombe National Park. Floristic Studies in Tropical Africa and Madagascar, Monogr. in Systematic Botany, Missouri Botanical Gardens, 64pp. ms.

Guinasso, N.L. and Schink, D.R., 1975, Quantitative estimates of biological mixing rates in abyssal sediment. *Jour. Geophys. Res.* 80:3032-3043.

Haberyan, K.A. and Hecky, R.E., 1987. The late Pleistocene and Holocene stratigraphy and paleolimnology of Lakes Kivu and Tanganyika. *Palaeogeog., Palaeoclim. Palaeoecol.* 61:169-197.

Hepper, F.N. (ed.), 1963. Flora of West Tropical Africa, 2nd ed., v.II. Published on behalf of Govts. of Nigeria, Ghana, Sierra Leone and Gambia by Crown

Agents for Overseas Govts. and Admin., London.

Hepper, F.N. (ed.), 1968. Flora of West Tropical Africa, 2nd ed., v.III, Part 1. Published on behalf of Govts. of Nigeria, Ghana, Sierra Leone and Gambia by Crown Agents for Overseas Govts. and Admin., London.

Levin, I., Kromer, B., Schoch-Fischer, H., Bruns, M., Munnich, M., Berdau, D., Vogel, J.C., and Munnich, K.O., 1985. 25 years of tropospheric ^{14}C observations in central Europe. *Radiocarbon* 27:1-19.

Litherland, A.E., and Beukens, R.P., 1995, Radiocarbon dating by atom counting. in Rutter,, N.W. and Catto, N.R. (eds.) Dating Methods for Quaternary Deposits. Geol. Assoc. Canada Geotext 2:117-123.

Livingstone, D.A., 1965. Sedimentation and the history of water level change in Lake Tanganyika. *Limnol. & Oceanogr.* 10:607-610.

Martens, K. 1993. On the taxonomy and zoogeography of the genus *Gomphocythere* SARS, 1924 (Crustacea, Ostracoda) with a description of a new species from the Nahal Dan (Israel). *Belgian Journal of Zoology*, vol. 123, pp. 39-54.

Martens, K. 1994. Ostracod speciation in ancient lakes: a review. In: Martens, K., Goddeeris, B., and Coulter, G. W. (Eds.). *Speciation in ancient lakes*, Archiv für hydrobiologie Beih. Ergebn. Limnol. Stuttgart, pp. 203-222.

Martens, K. 1997. Recent non-marine Ostracoda. Lake Tanganyika Biodiversity Project - *Workshop*, Kigoma, Tanzania Feb 2-10, 13 pp.

McKee, B.A., Nittrouer, C.A., and DeMaster, D.J., 1983, The concepts of sediment deposition and accumulation applied to the continental shelf near the mouth of the Yangtze River. Geology 11:631-633.

Nittrouer, C.A., Sternberg, R.W., Carpenter, R., and Bennett, J.T., 1979, The use of ^{210}Pb geochronology as a sedimentological tool: Applications to the Washington continental shelf. Marine Geology 31:297-316.

Nydal, R., and L`vseth, K., 1983, Tracing bomb ^{14}C in the Atmosphere 1962-1980. *Jour. Geophs. Res.* 88:3621-3642.

O'Reilly, C. 1998. Effects of deforestation on epilithic productivity in Lake Tanganyika. Abstract.

Palacios-Fest, M. R. 1994. Trace element shell chemistry of continental ostracodes and the applicability of experimentally-derived multiple regression models to paleoenvironmental reconstructions in southwestern North America. *Ph. D. Dissertation, Department of Geosciences, University of Arizona*, 279 pp.

Park, L. E. 1995. Assessing diversification patterns in an ancient tropical lake: Gomphocythere (Ostracoda) in Lake Tanganyika. Dissertation, University of Arizona, Tucson, 317 pp.

Patchett, P.J., 1992, Isotopic studies of Proterozoic crustal growth and evolution. *in* Condie, K.C. (ed.) *Proterozoic Crustal Evolution* ch. 13:481-508.

Pohill, R.M. (ed.) Series in multiple volumes/dates. Flora of Tropical East Africa. Published on behalf of the East African Community. A.A. Balkema, Rotterdam.

Pope, G.V. (ed.) Series in multiple volumes/dates. Flora Zambesiaca. Royal Bot. Gardens, Kew, London.

Rome, D. R. 1962. Resultats Scientifiques: Exploration Hydrobiologique du Lac Tanganyika (1946-1947). Institute Royale des Sciences Naturelles de Belgique, Vol. III, Fasc. 8, 305 pp.

Schluter, T., 1997, Geology of East Africa. Gebruder Borntraeger, Berlin, 484pp.

Vincens, A., 1989. Paleoenvironments du bassin Nord-Tanganyika (Zaire, Burundi, Tanzanie) au cours de 13 derniers mille ans: apport de la palynologie. *Rev. Paleobot. Palynol.* 61:69-88.

Vincens, A., 1991. Late Quaternary vegetation history of the South-Tanganyika basin. Climatic implications in South Central Africa. *Palaeogeog. Palaeoclim. Palaeoecol.* 86:207-226.

Vincens, A., 1993. Nouvelle sequence pollinique du lac Tanganyika. 30,000 ans d'histoire botanique et climatique du bassin Nord. *Rev. Paleobot. Palynol.* 78:381-394.

Wells, T. M., A. S. Cohen, L. E. Park, D. L. Dettman and B. A. McKee. (1999, in press). Ostracode stratigraphy and paleoecology from surficial sediments of Lake Tanganyika, Africa. *Journal of Paleolimnology*.

Xia, J., Ito, E., Engstrom, D.R. 1977. Geochemistry of ostracode calcite: part 1. An experimental determination of oxygen isotope fractionation. *Geochimica et Cosmochimica Acta*. 61:377-382.

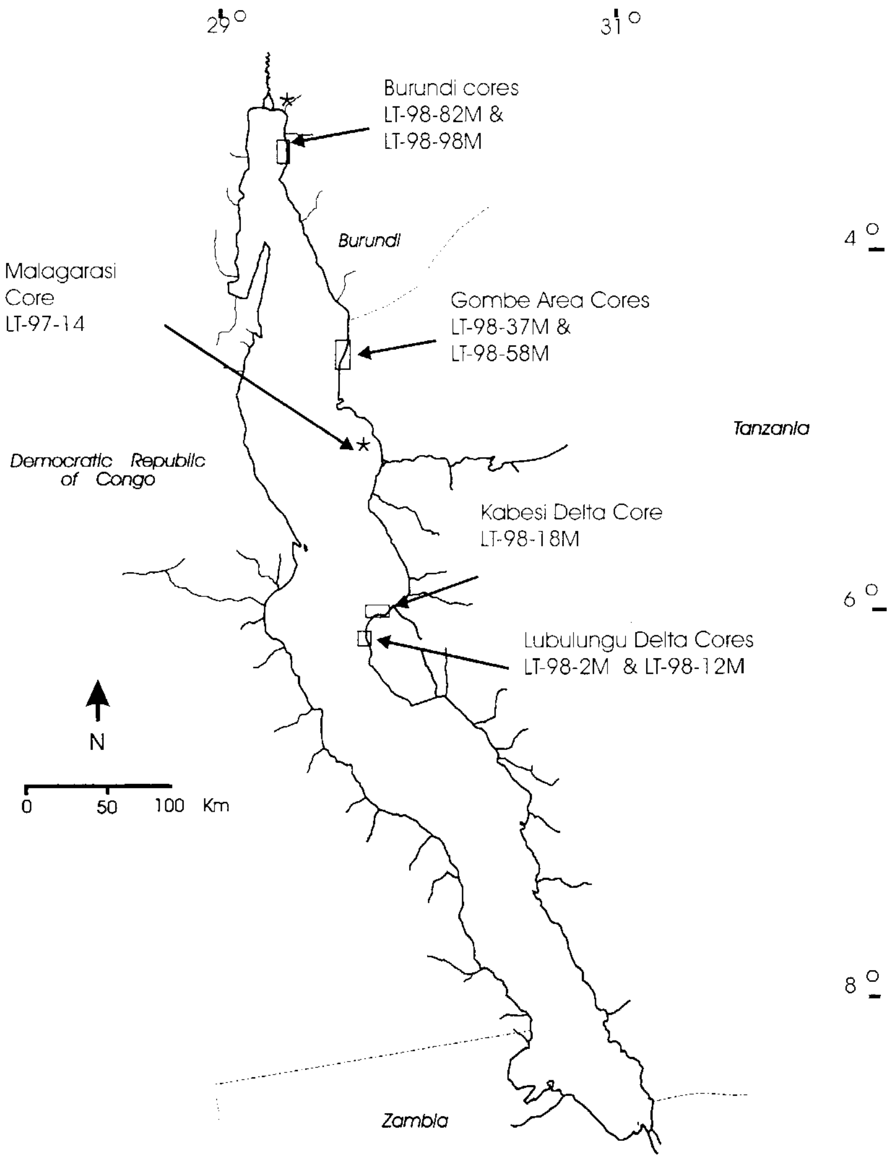


Figure 3.1 Lake Tanganyika, showing areas investigated in this study

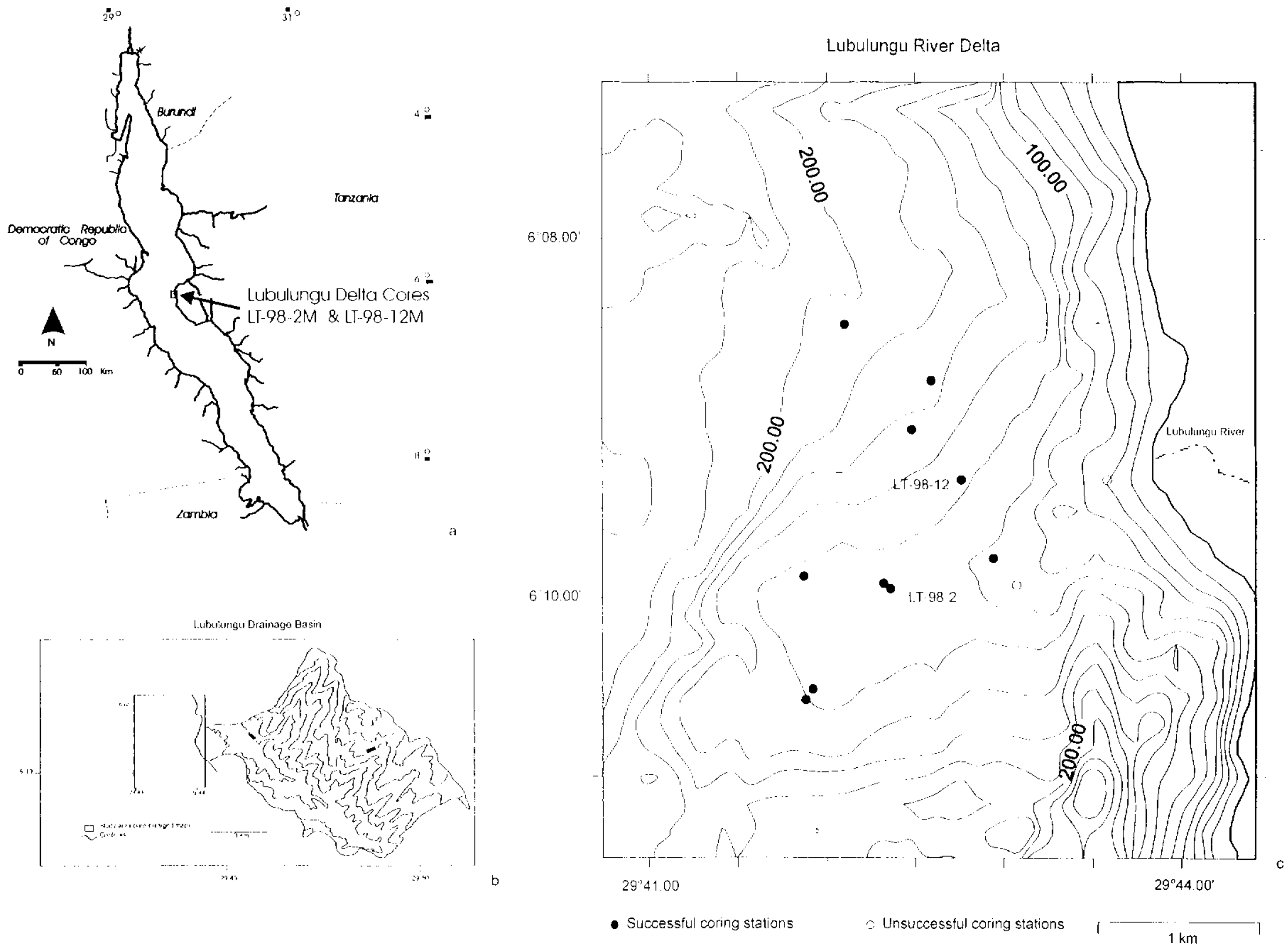


Fig. 3.2. Lubulungu River Delta bathymetric map showing coring sites, specifically: a) area of study, b) drainage basin and c) sites LT-98-2 and LT-98-12. (Topographic closure hole at the southeast corner of map appears to be an artifact of contouring narrow channels.)

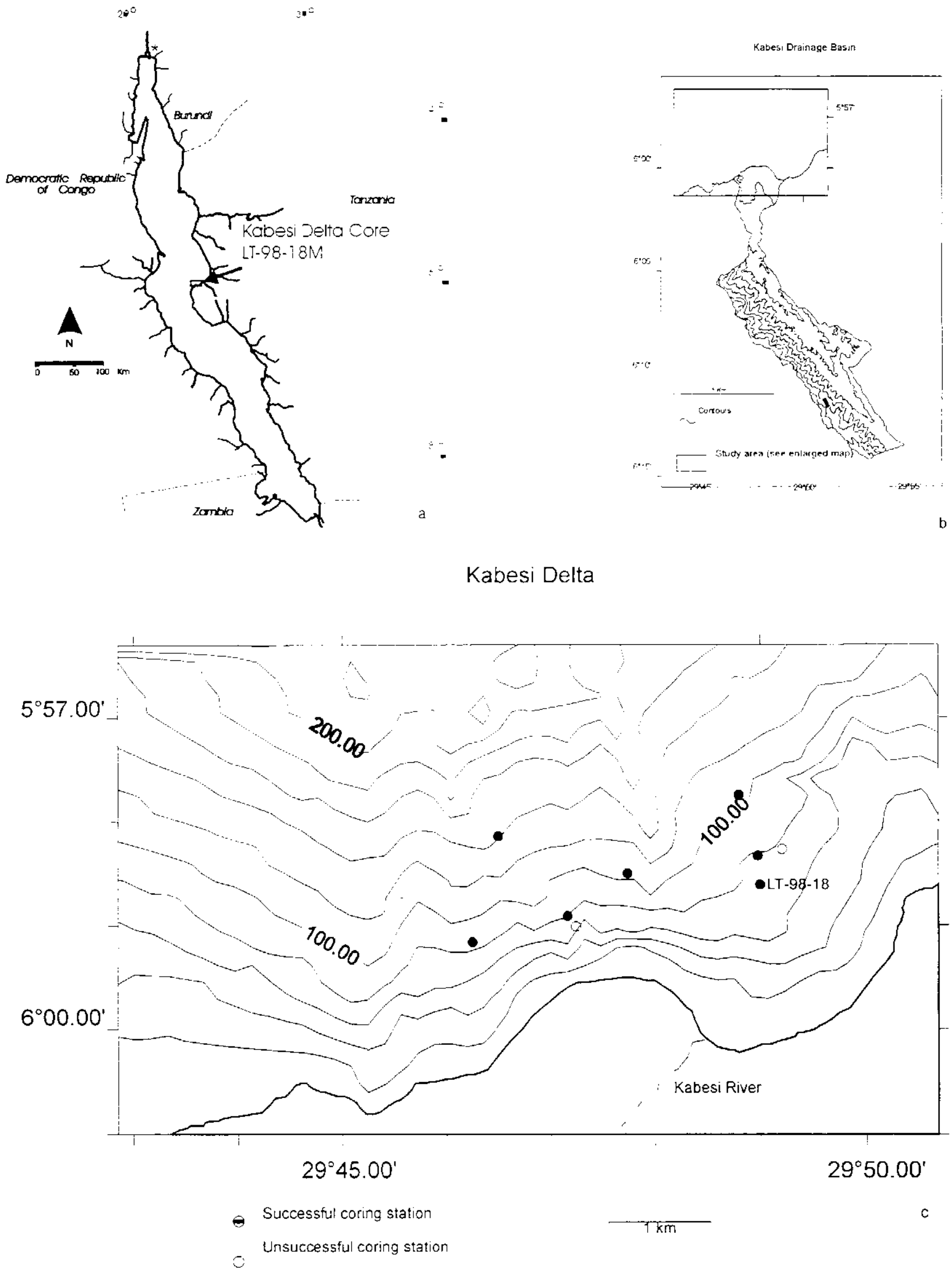


Fig. 3.3. Kabesi River Delta bathymetric map showing coring sites, specifically: a) area of study, b) drainage basinand c) site LT-98-18. (Topographic closure holes at the northern part of the map appear to be an artifact of contouring narrow channels.)

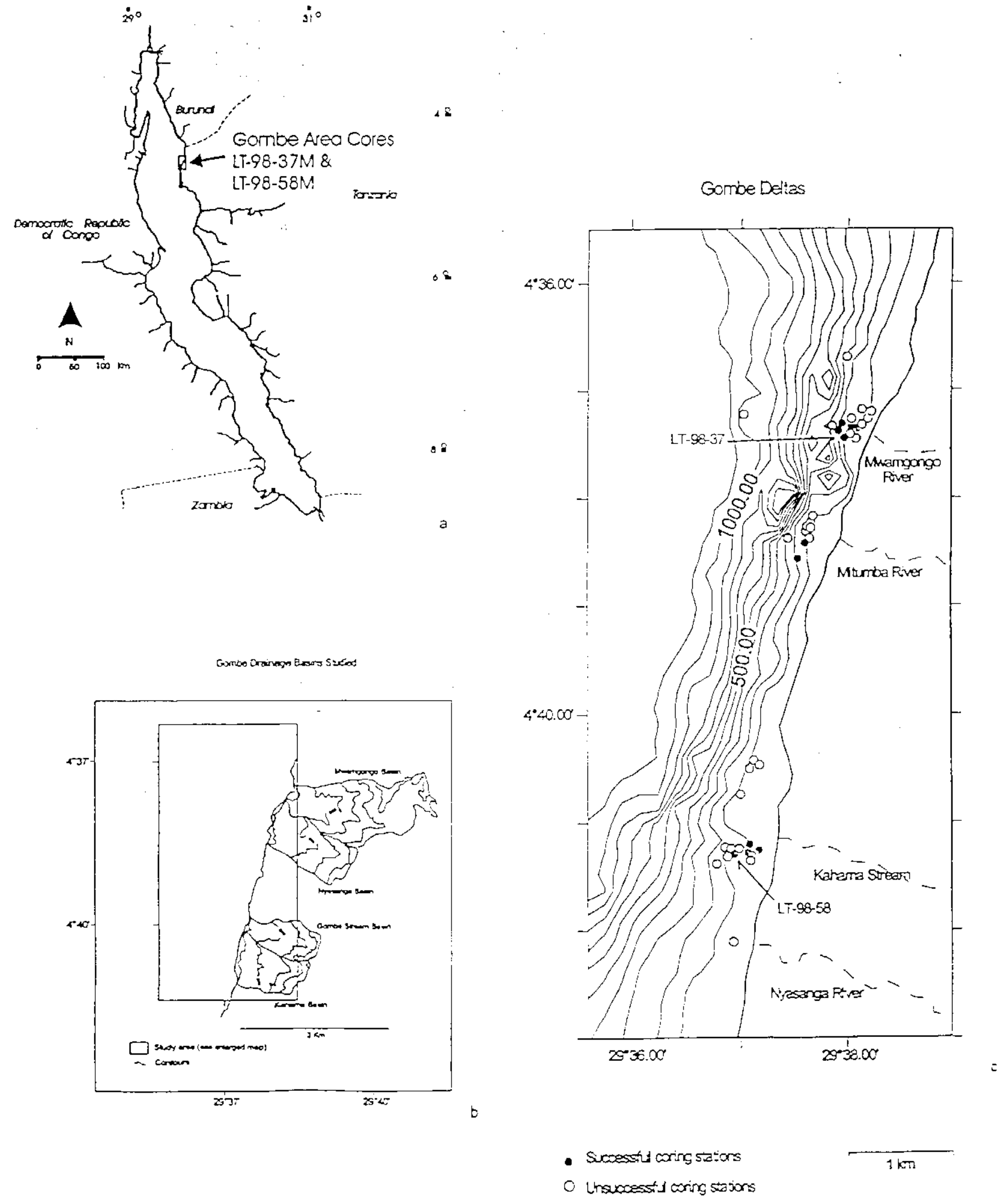


Fig. 3.4. Gombe area deltas bathymetric map showing coring stations, specifically: a) areas of study, b) drainage basins, and c) sites LT-98-37 and LT-98-58

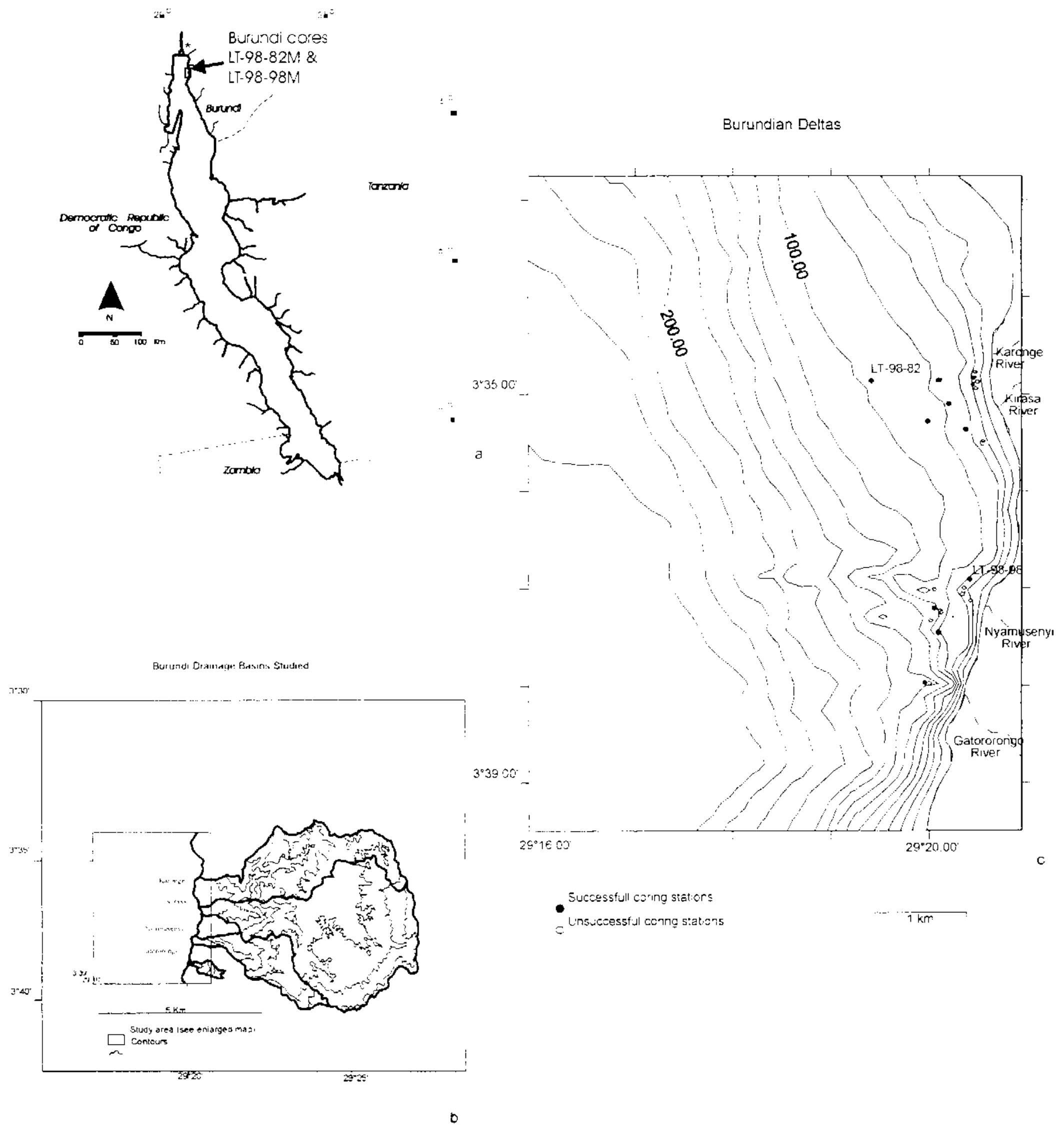


Fig. 3.5. Burundi area deltas bathymetric map showing coring stations, specifically: a) areas of study, b) drainagebasins, and c) sites LT-98-82 and LT-98-98

Fig. 3.6 Lithostratigraphy of LT-98-2M (Center of Lubulungu Delta Plain) 49 cm, 110m water depth

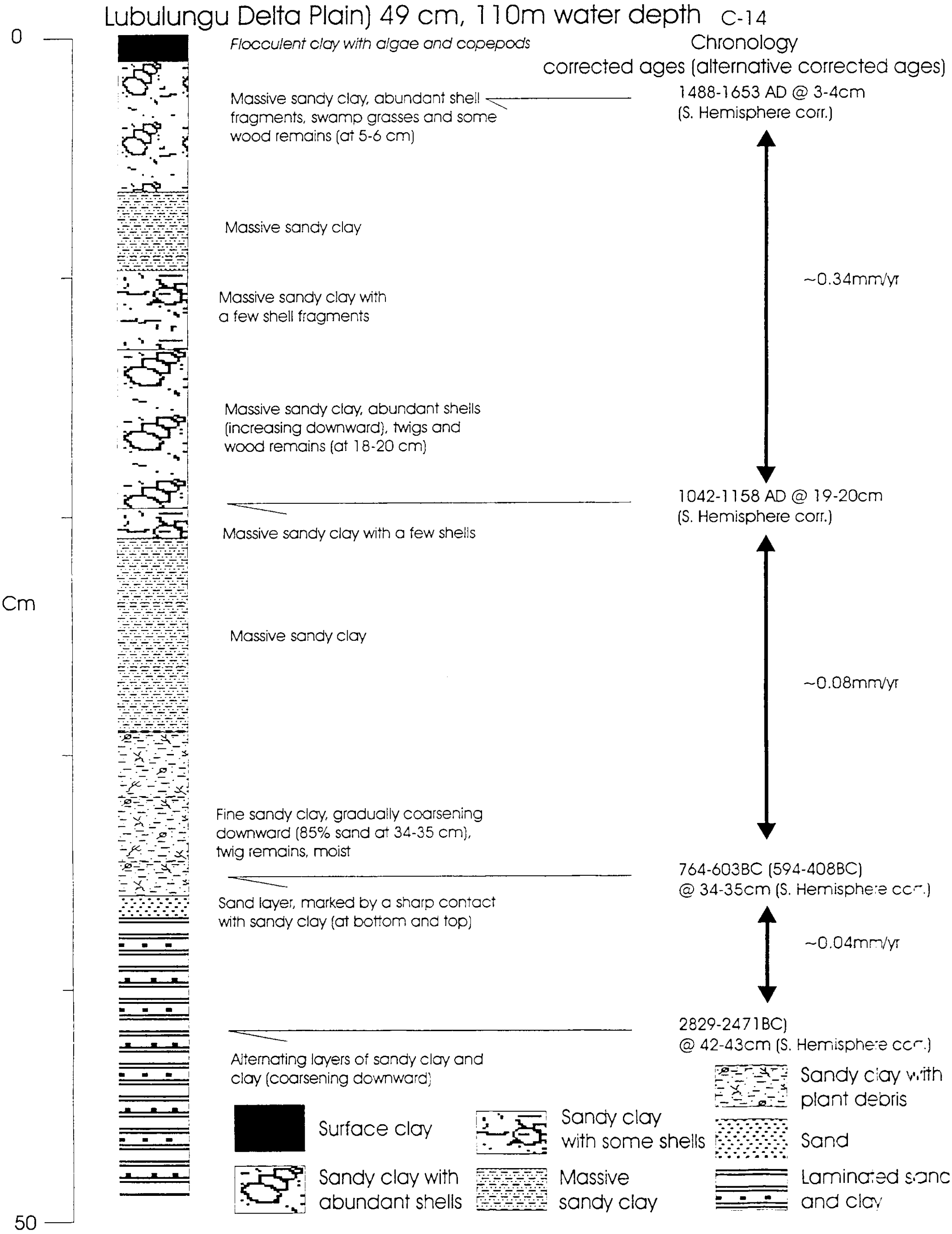


Fig. 3.6 Lithostratigraphy of LT-98-2M (Center of Lubulungu Delta Plain) 49 cm, 110m water depth

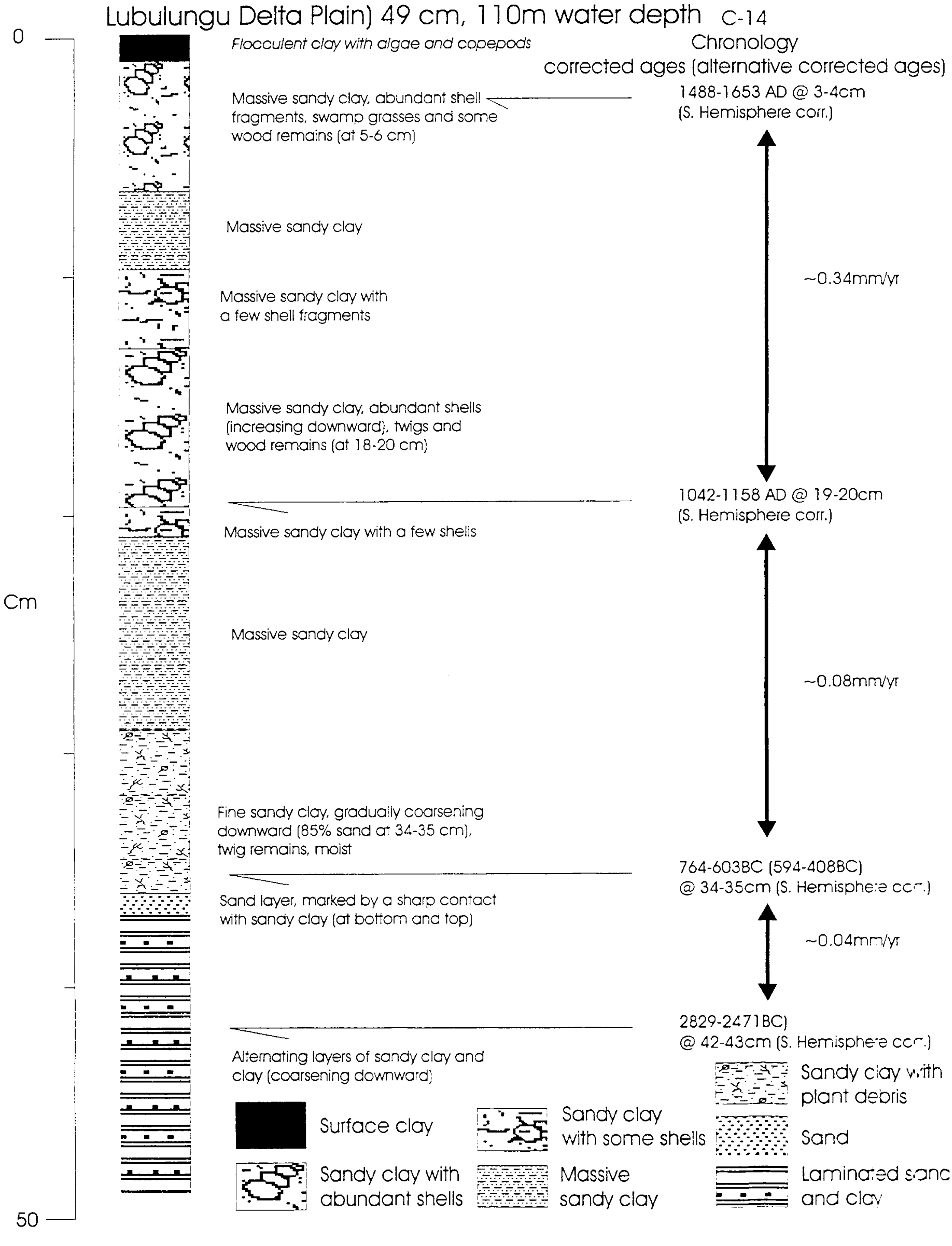


Fig. 3.7 Lithostratigraphy of LT-98-12M (just north of Lubulungu Delta Plain) 40 cm, 126 m water depth

C-14
Chronology
corrected ages
(alternative corrected ages)

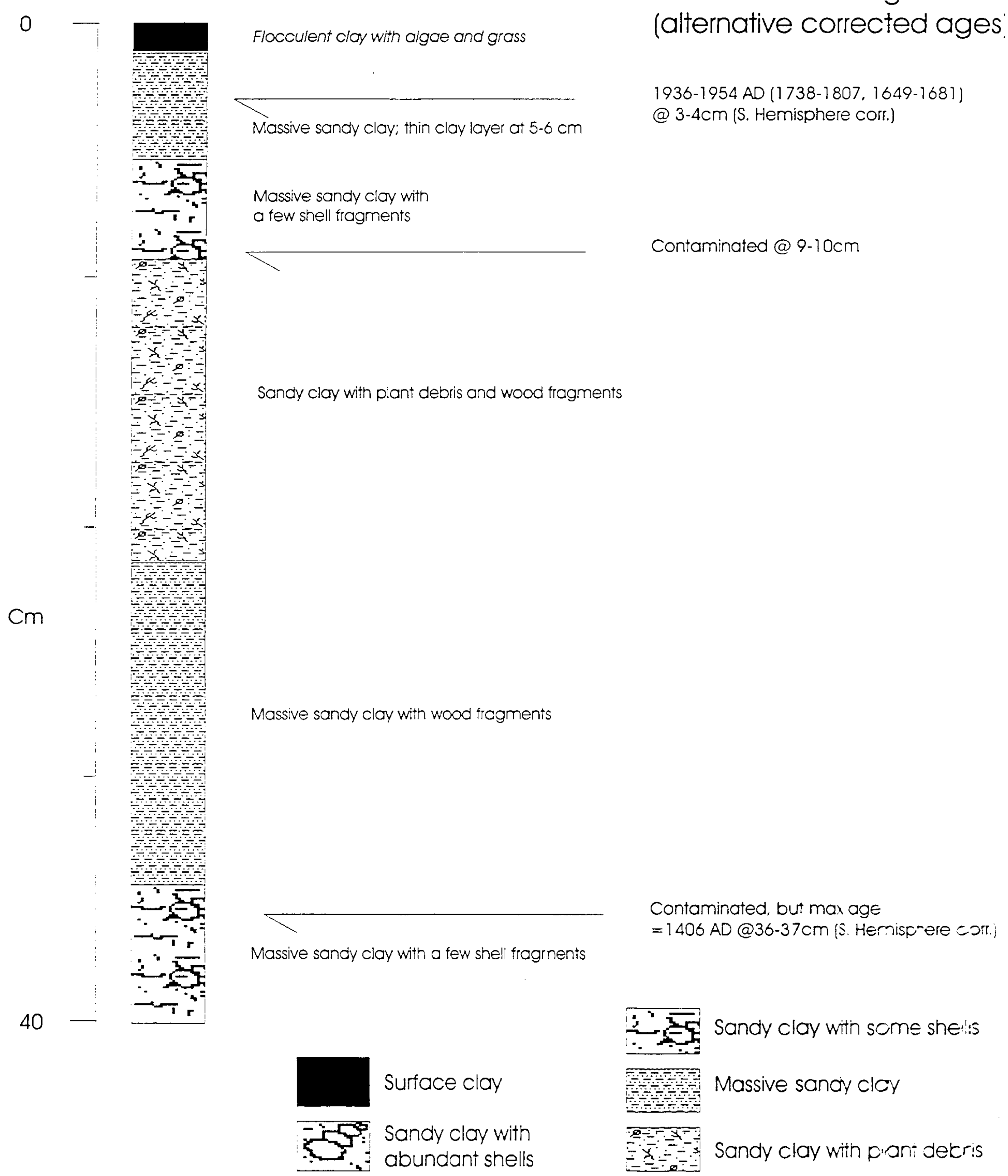


Fig. 3.8 Lithostratigraphy of LT-98-18M (Kabesi River Delta) 42 cm, 75 m water depth

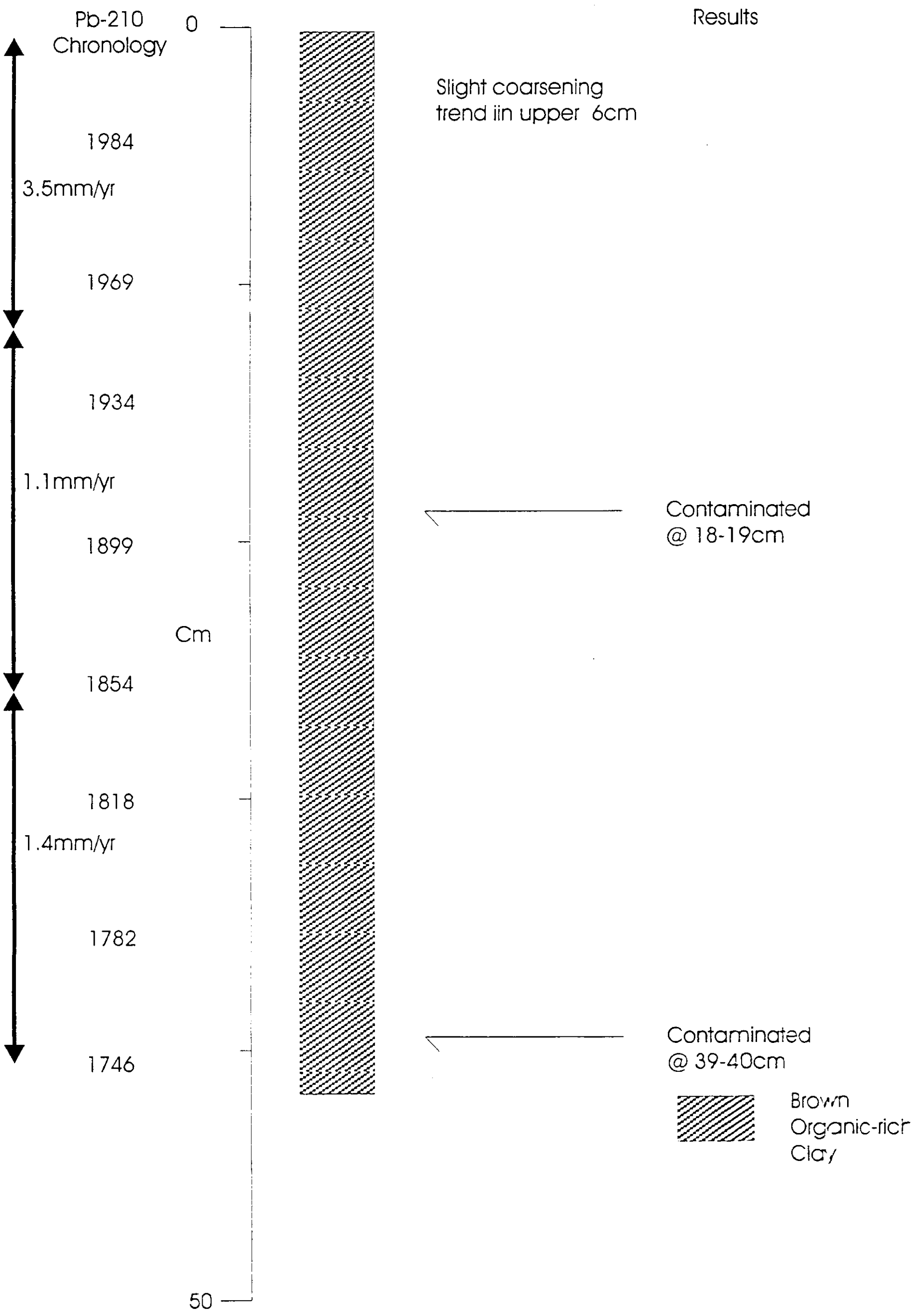


Fig. 3.9 Lithostratigraphy of LT-98-58M (Nyasanga/Kahama) 42 cm, 76 m water depth

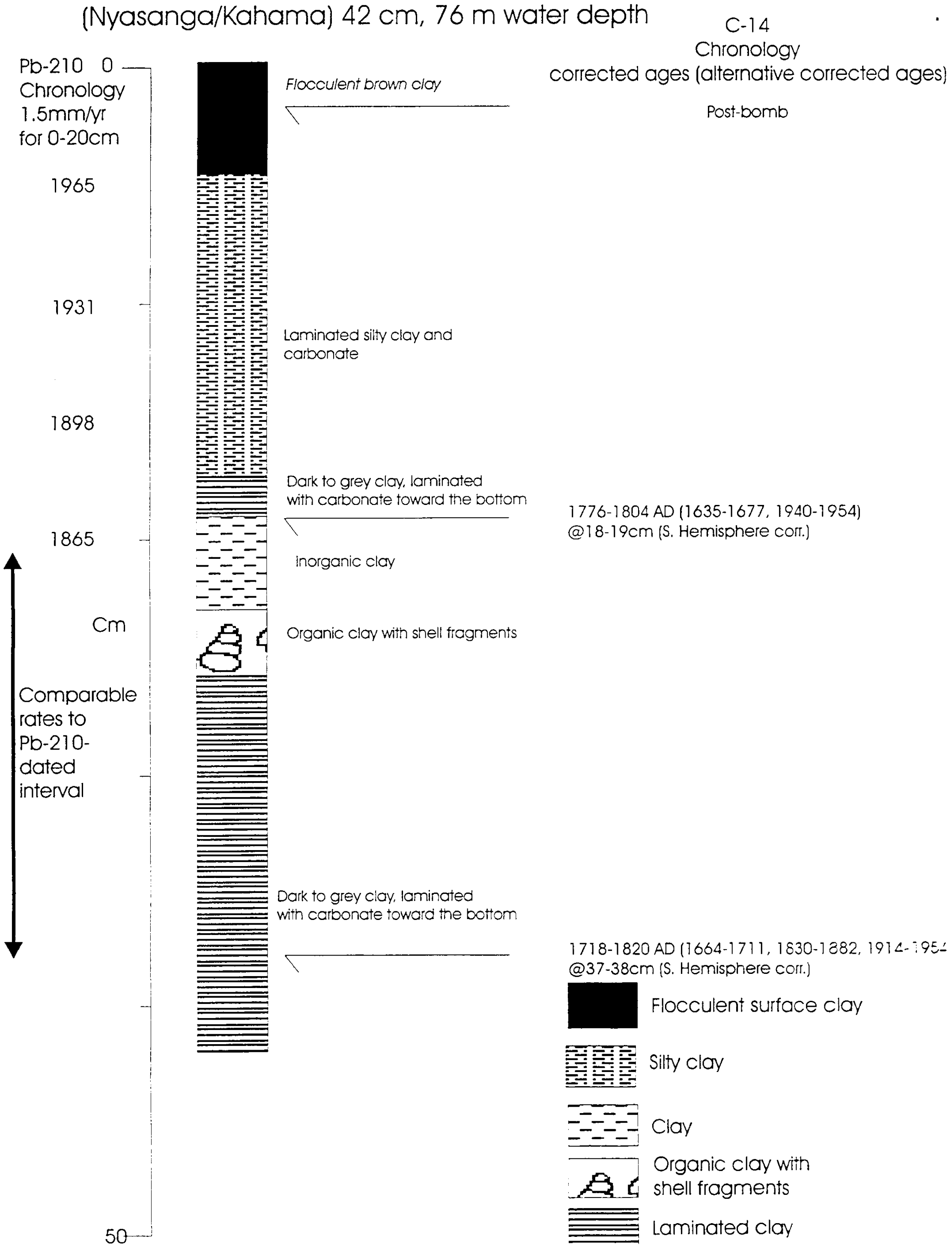


Fig. 3.10 Lithostratigraphy of LT-98-37M
(Mwamgongo River Delta) 45 cm, 95m water depth

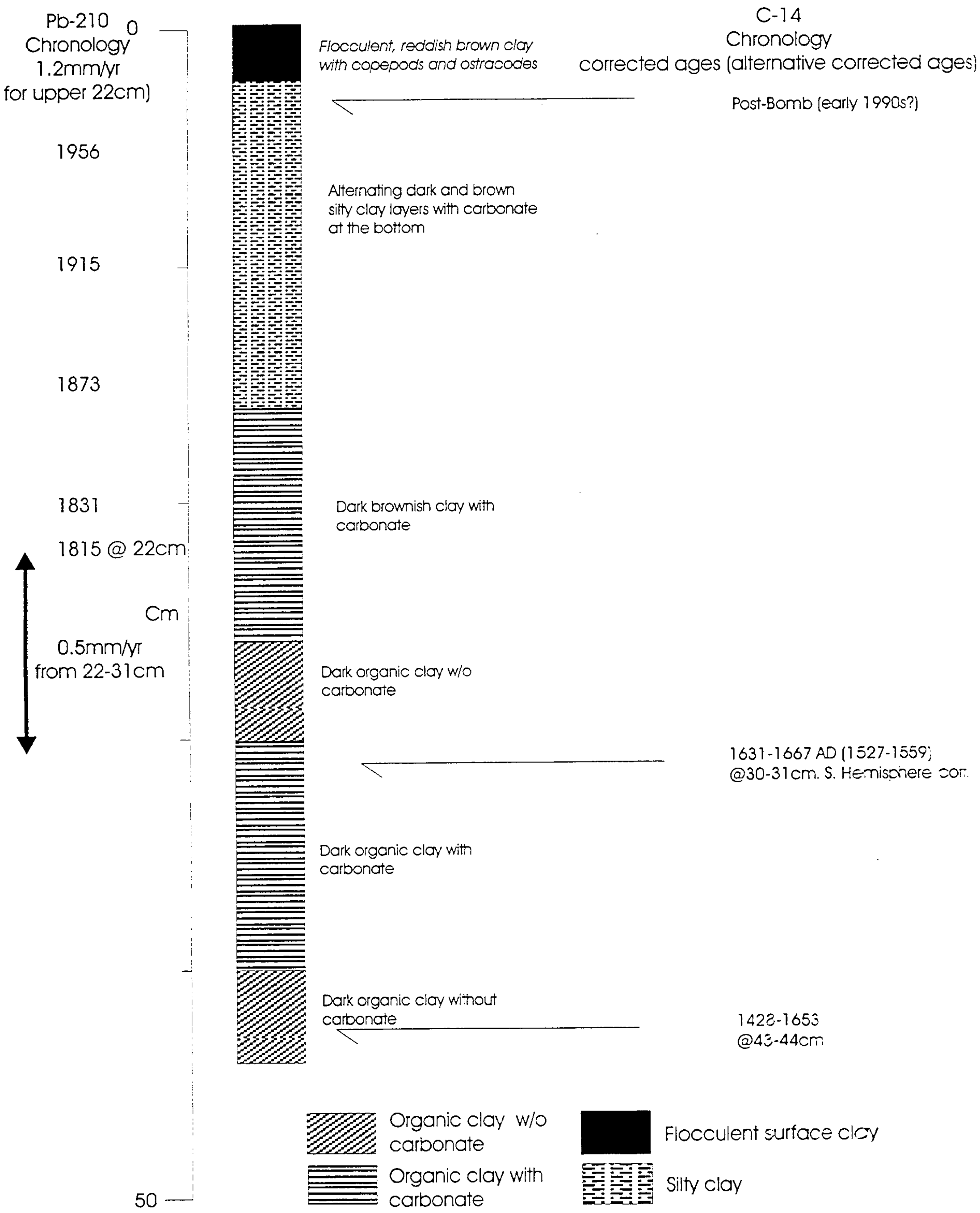


Fig. 3.11 Lithostratigraphy of LT-98-98M (N of Nyamusenyi River) 37 cm, 60 m water depth

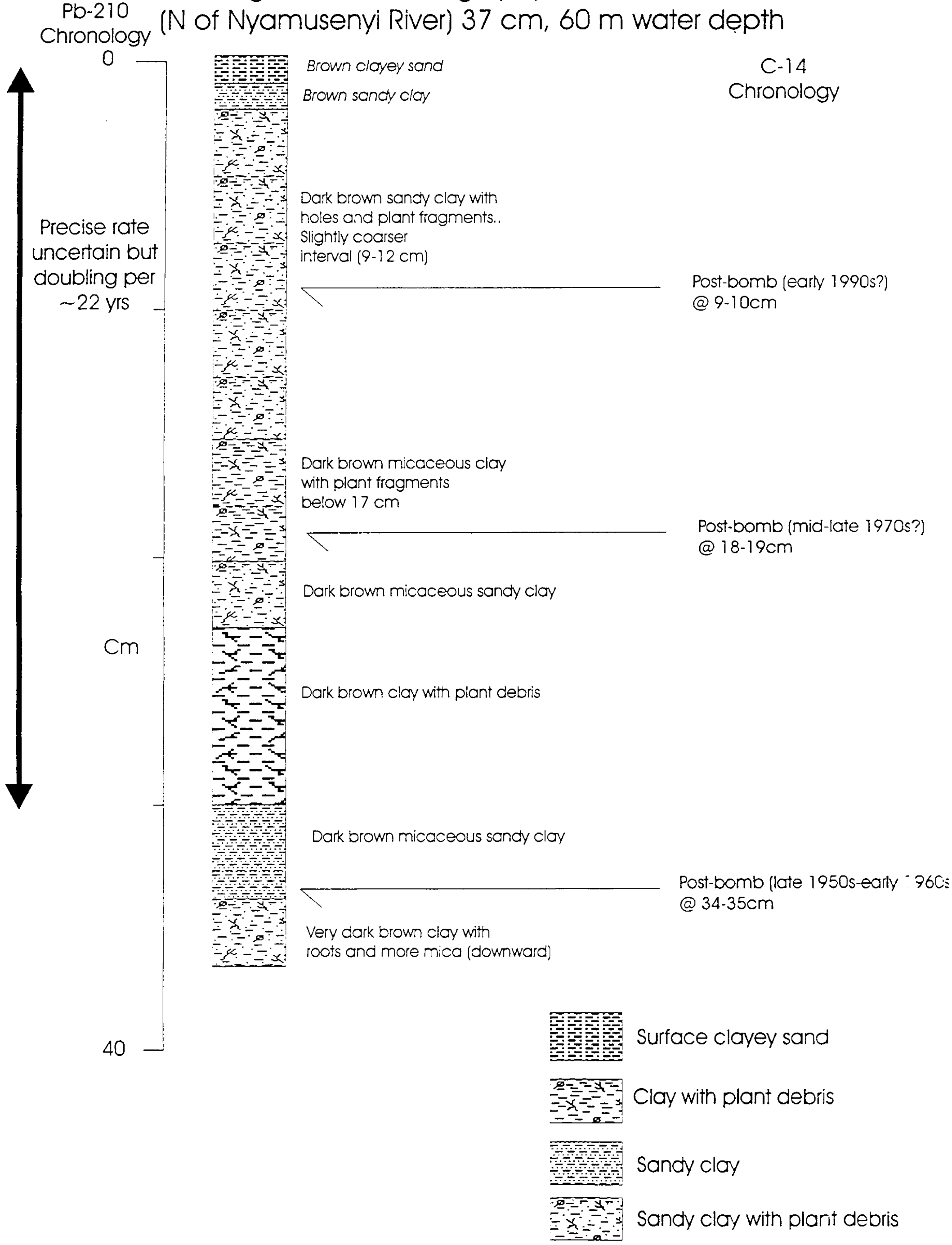


Fig. 3.12 Lithostratigraphy of LT-98-82M (S. of Karonge River) 46 cm, 96 m water depth

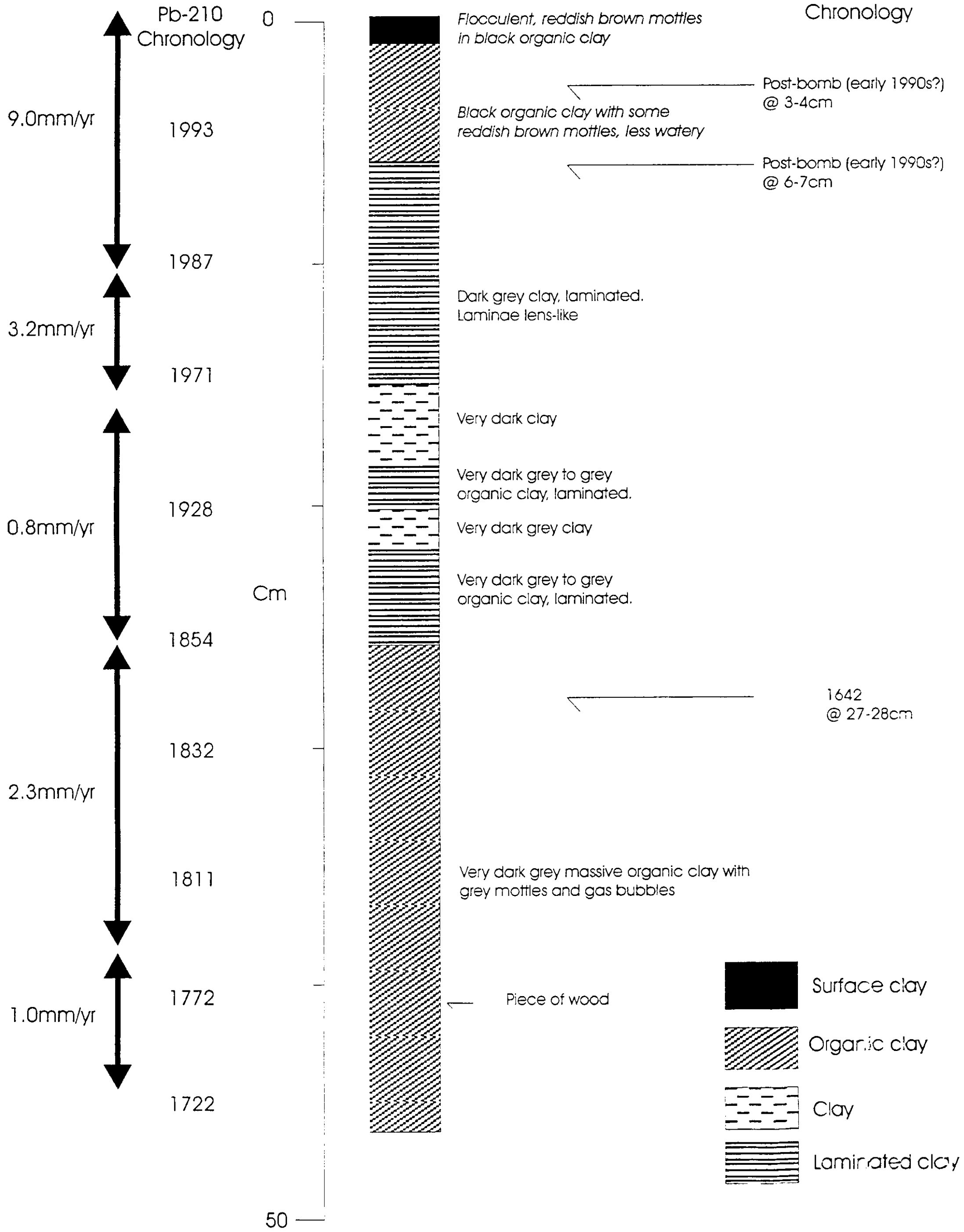


Fig. 3.13 LT-98-18M excess ^{210}Pb (dpm/gm) and age model

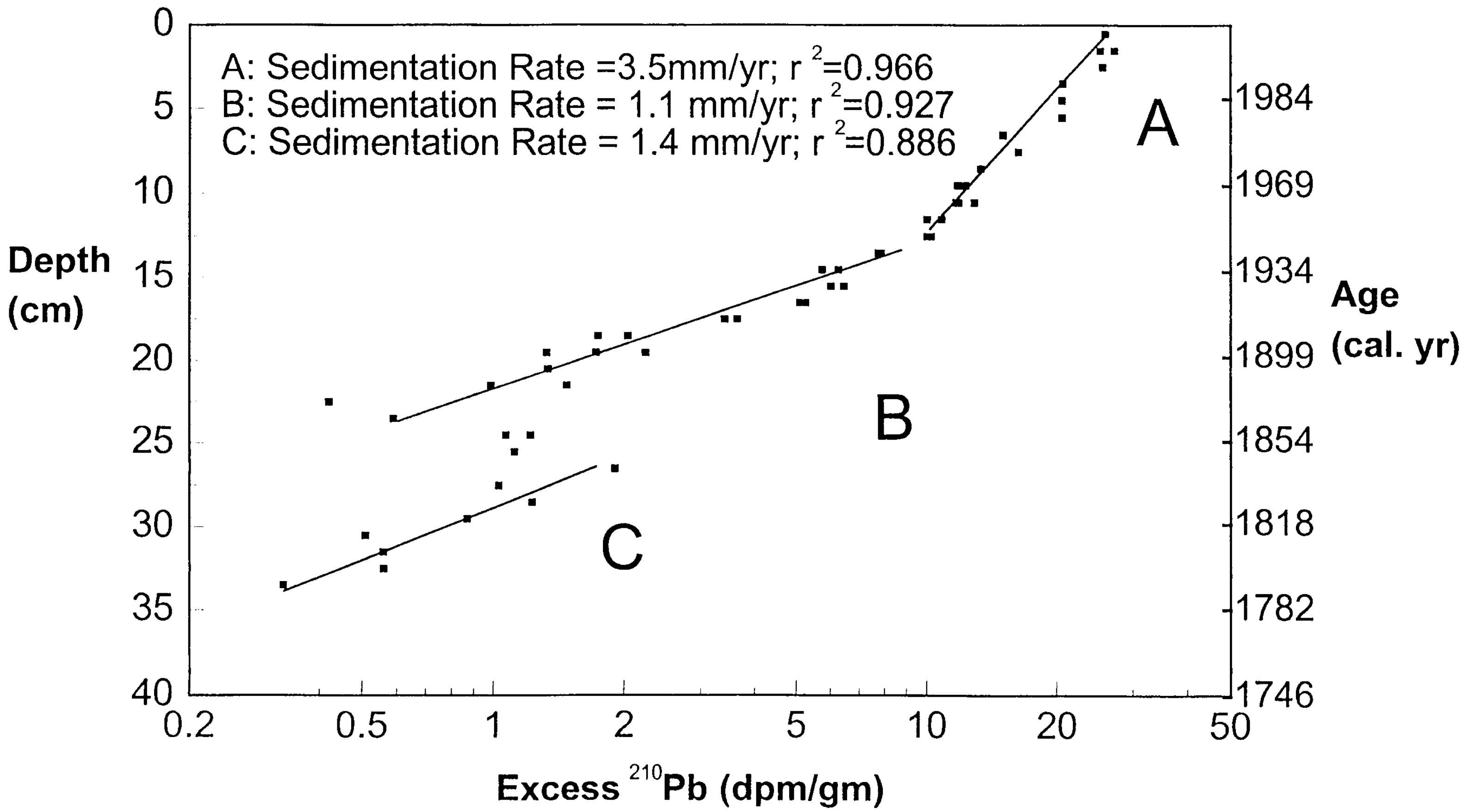


Fig. 3.14 LT-98-58M excess ^{210}Pb (dpm/gm) and age model

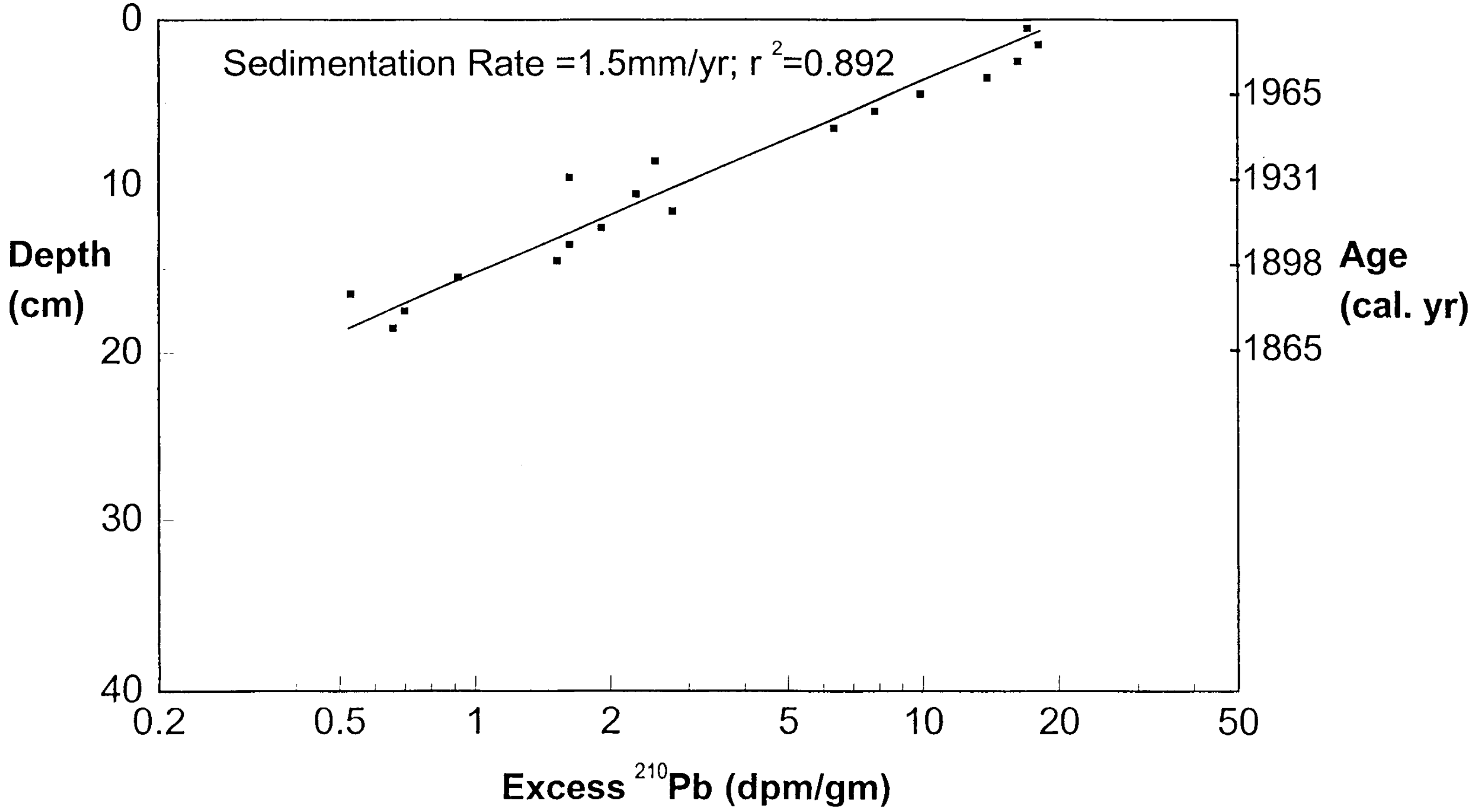


Fig. 3.15 LT-98-37M excess ^{210}Pb (dpm/gm) and age model

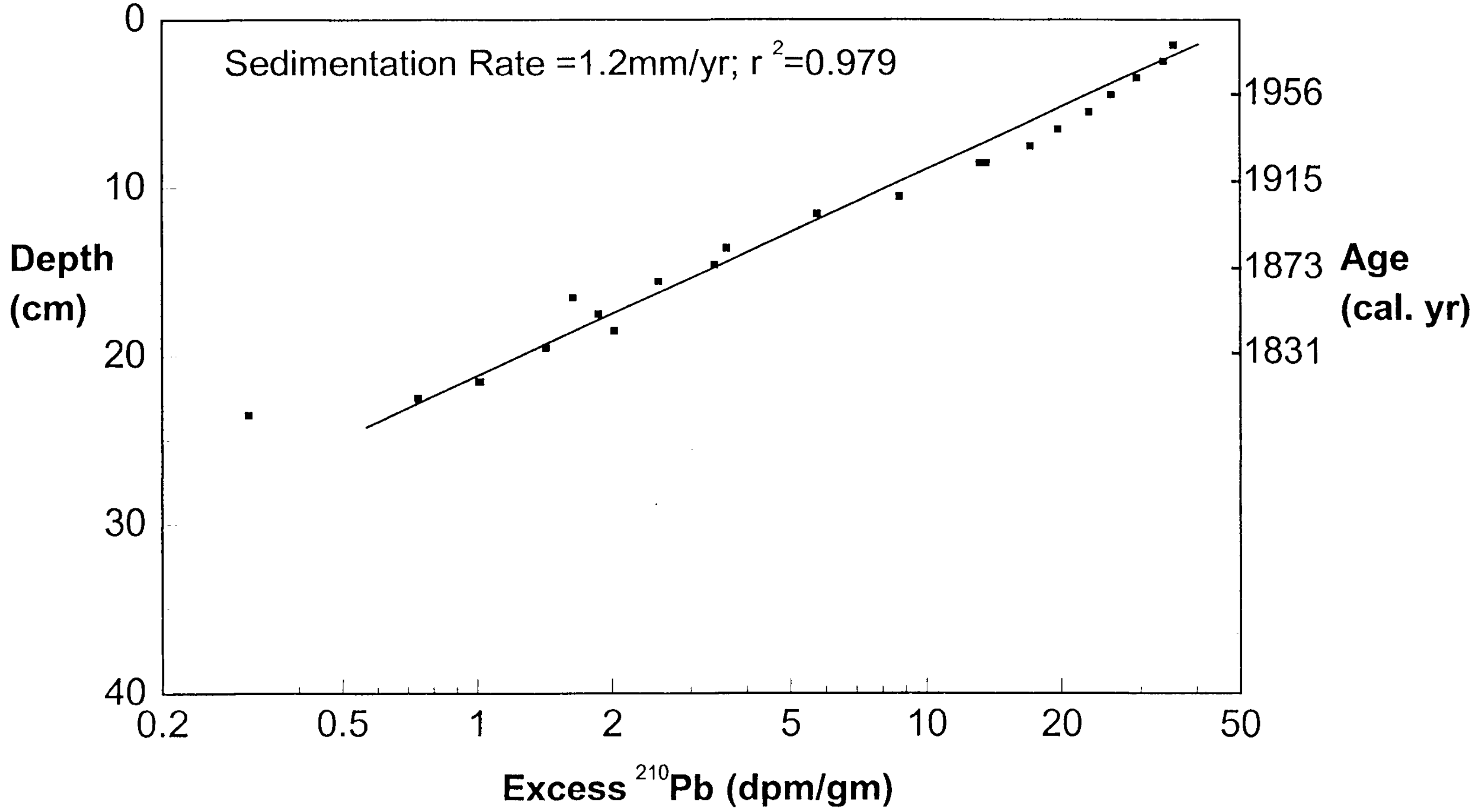


Fig. 3.16 LT-98-82M excess ^{210}Pb (dpm/gm) and age model

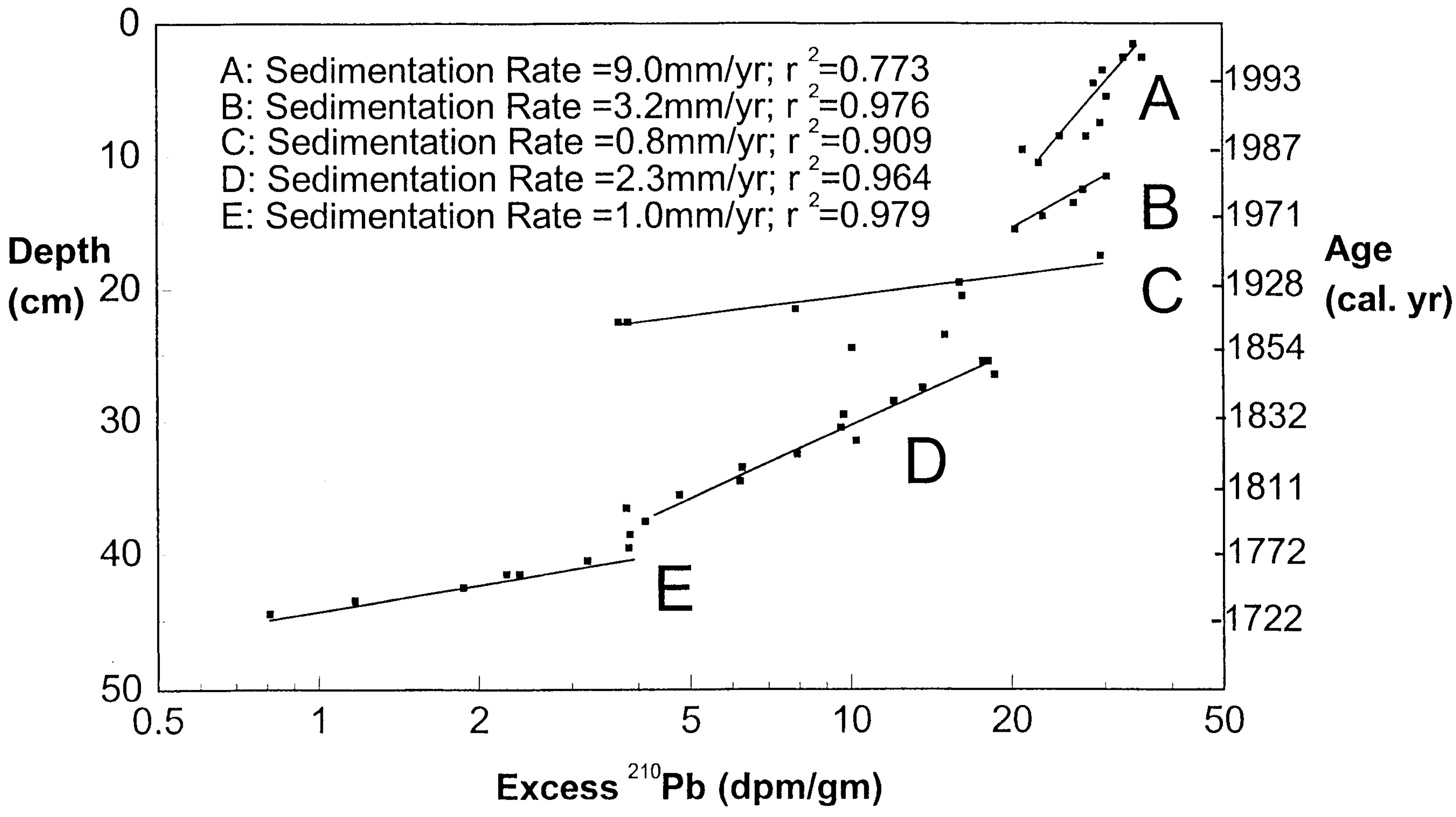


Fig. 3.17 LT-98-98M excess ^{210}Pb (dpm/gm)

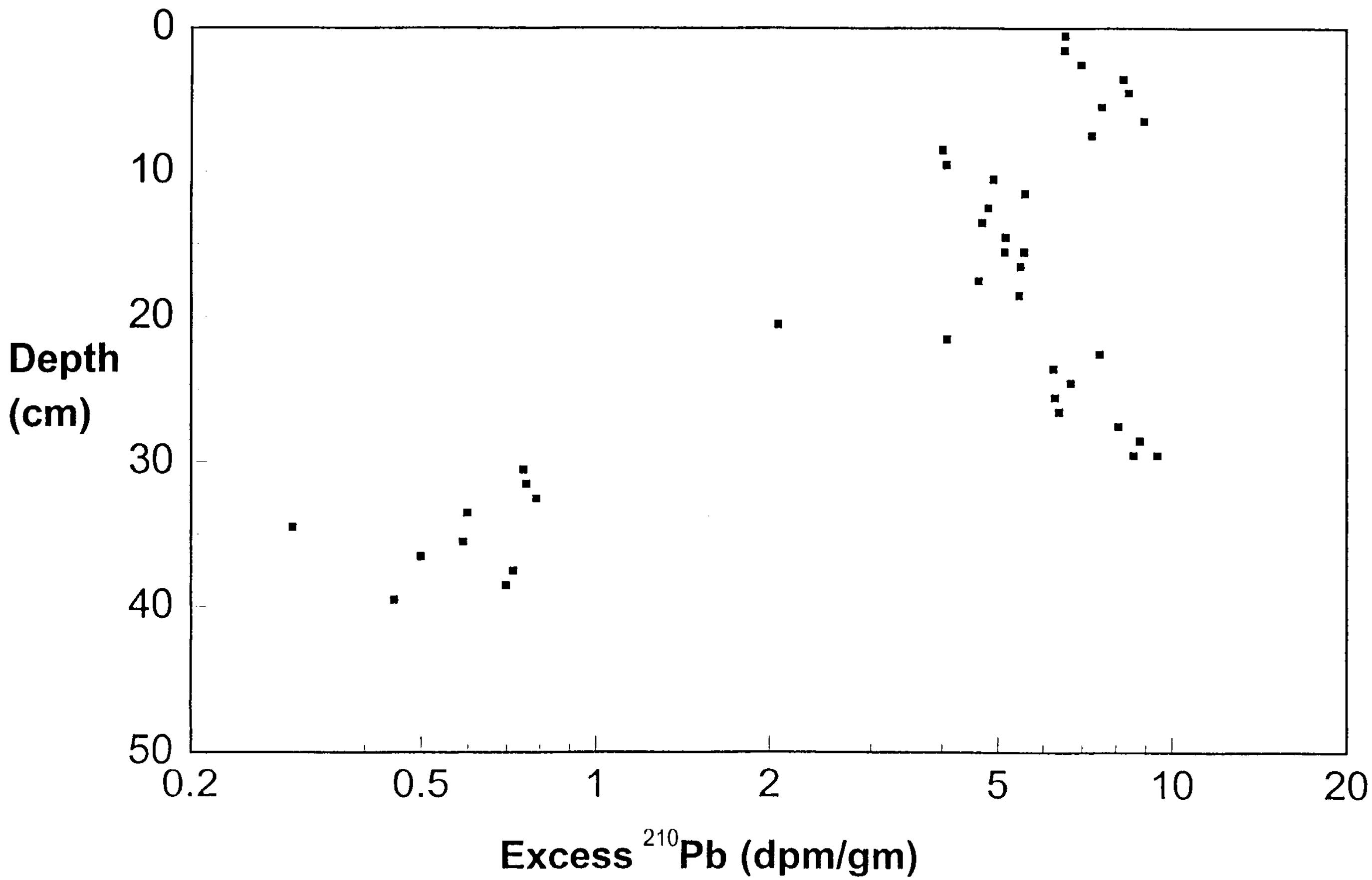
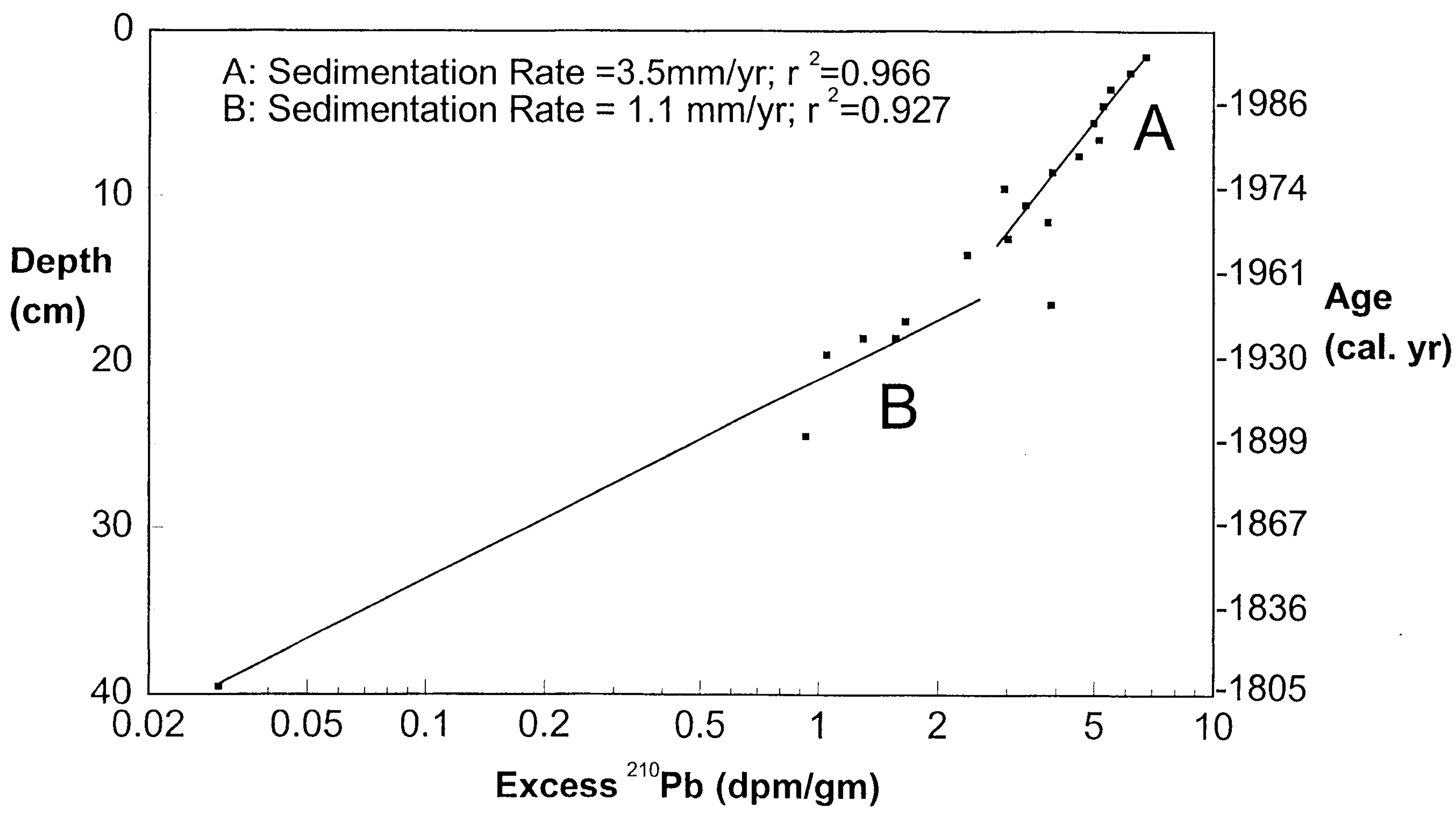


Fig. 3.18 LT-97-14V excess ^{210}Pb (dpm/gm) and age model



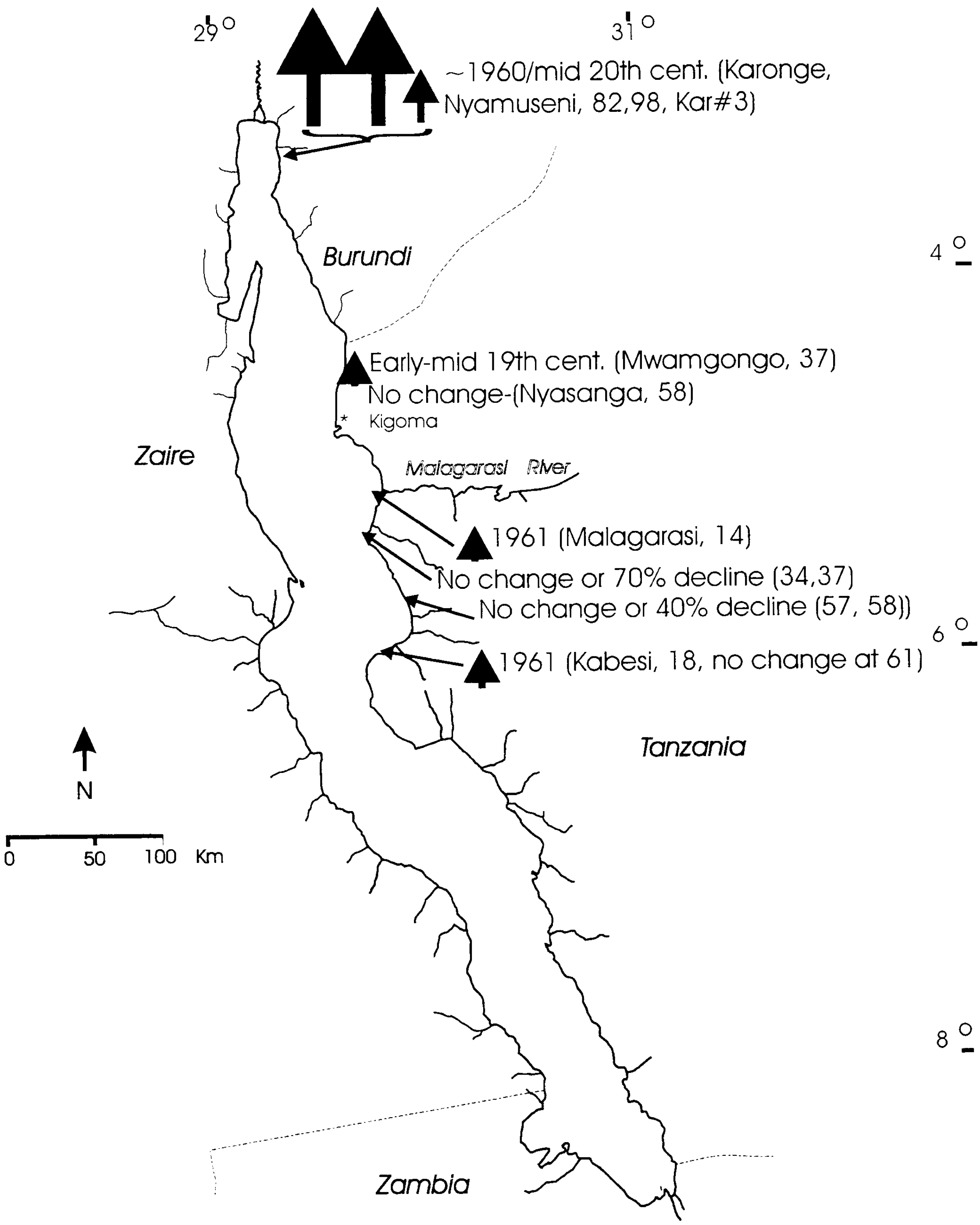
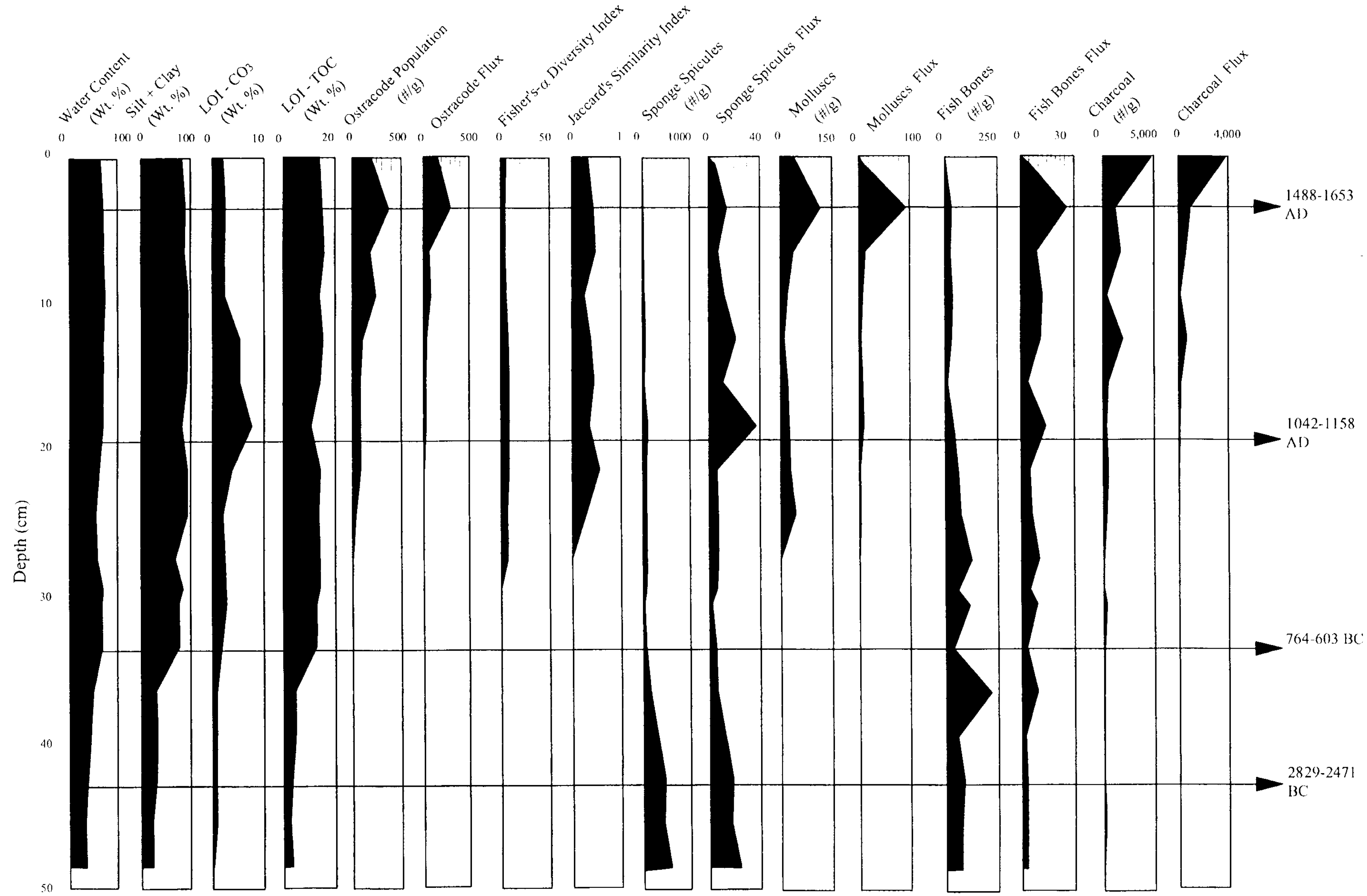


Figure 3.19. Changes in sedimentation rates in the 19th/20th century

Core LT-98-2M

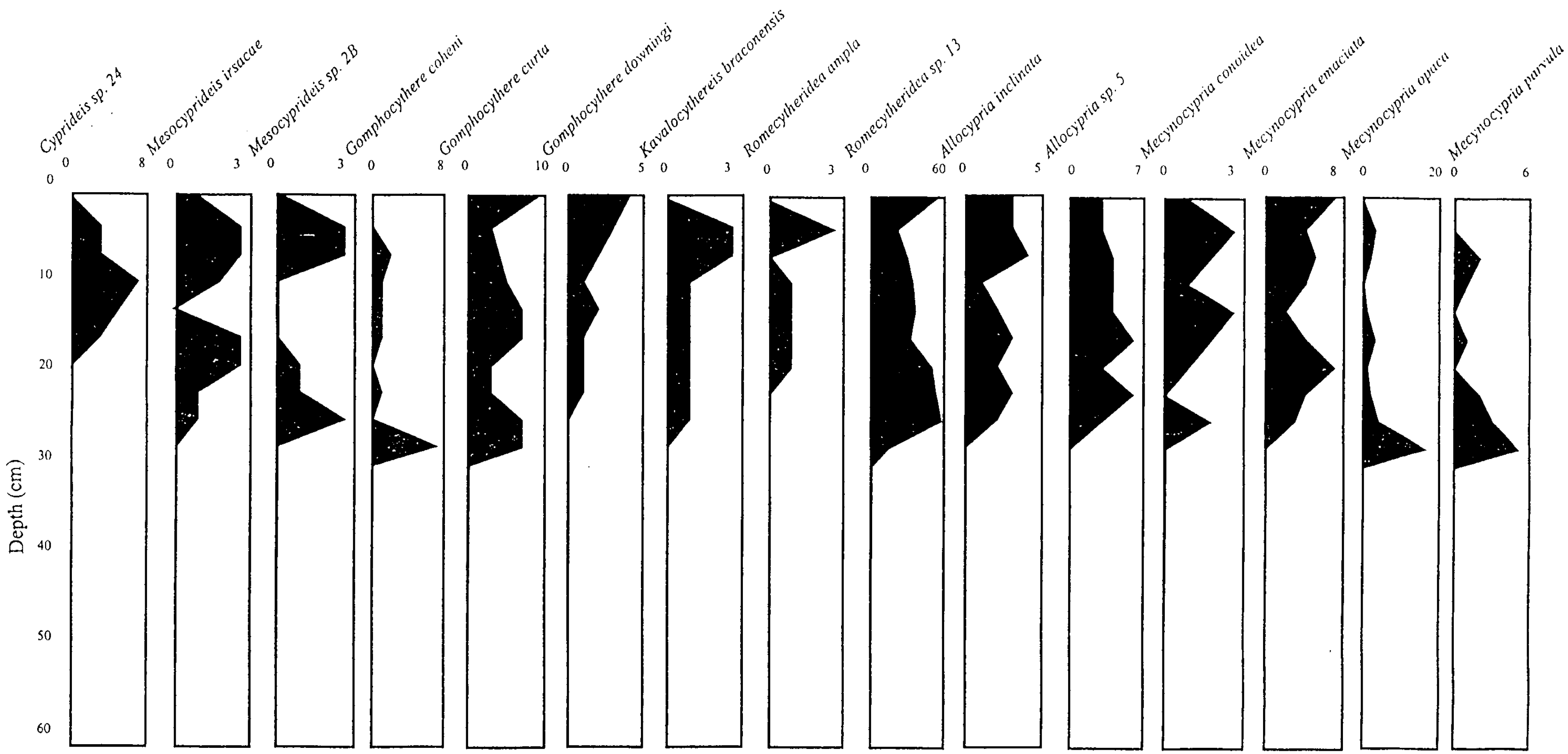
Fig. 3.20a



Core LT-98-2M

Fig. 3.20b(i)

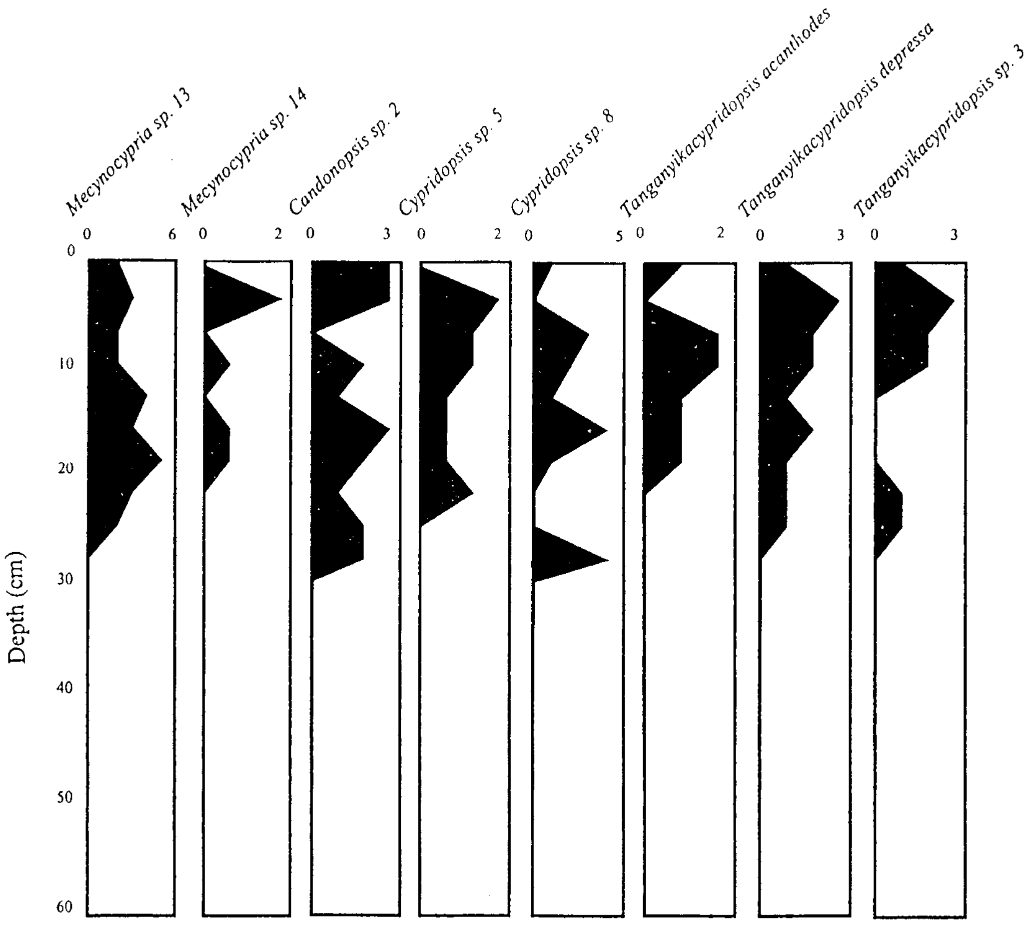
Common Ostracode Species



Core LT-98-2M

Fig. 3.20b(ii)

Common Ostracode Species



Core LT-98-2M

Fig. 3.20b(iii)

Rare Ostracode Species

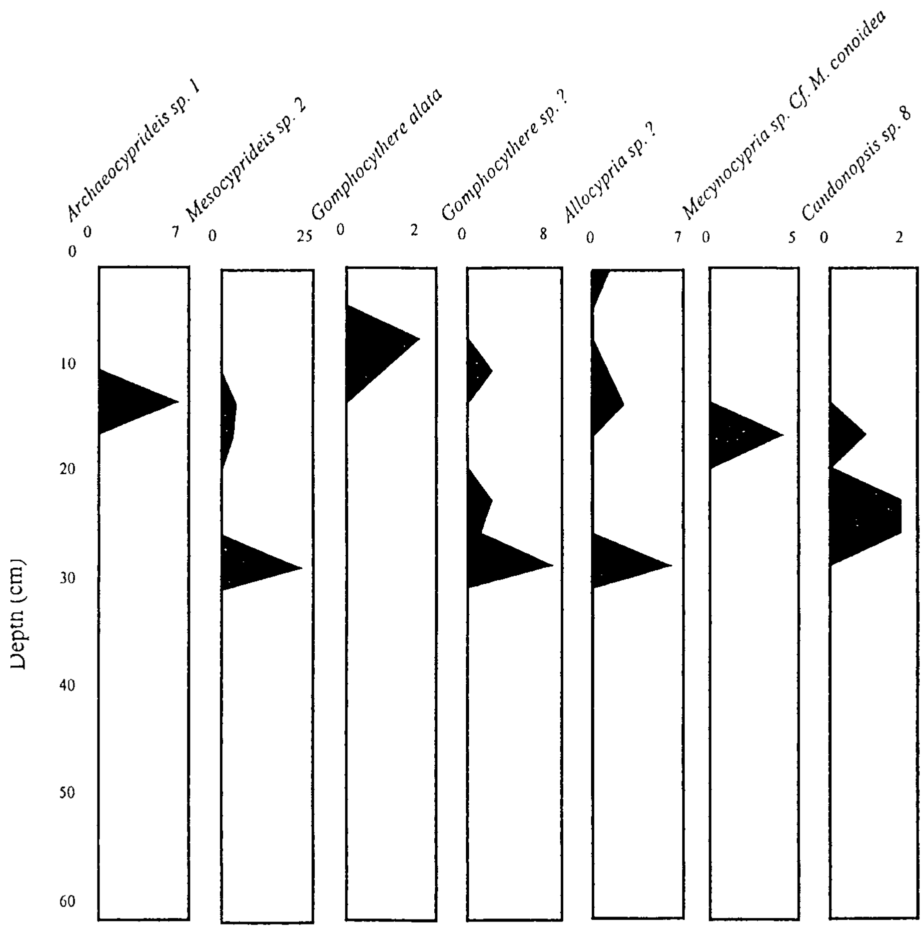
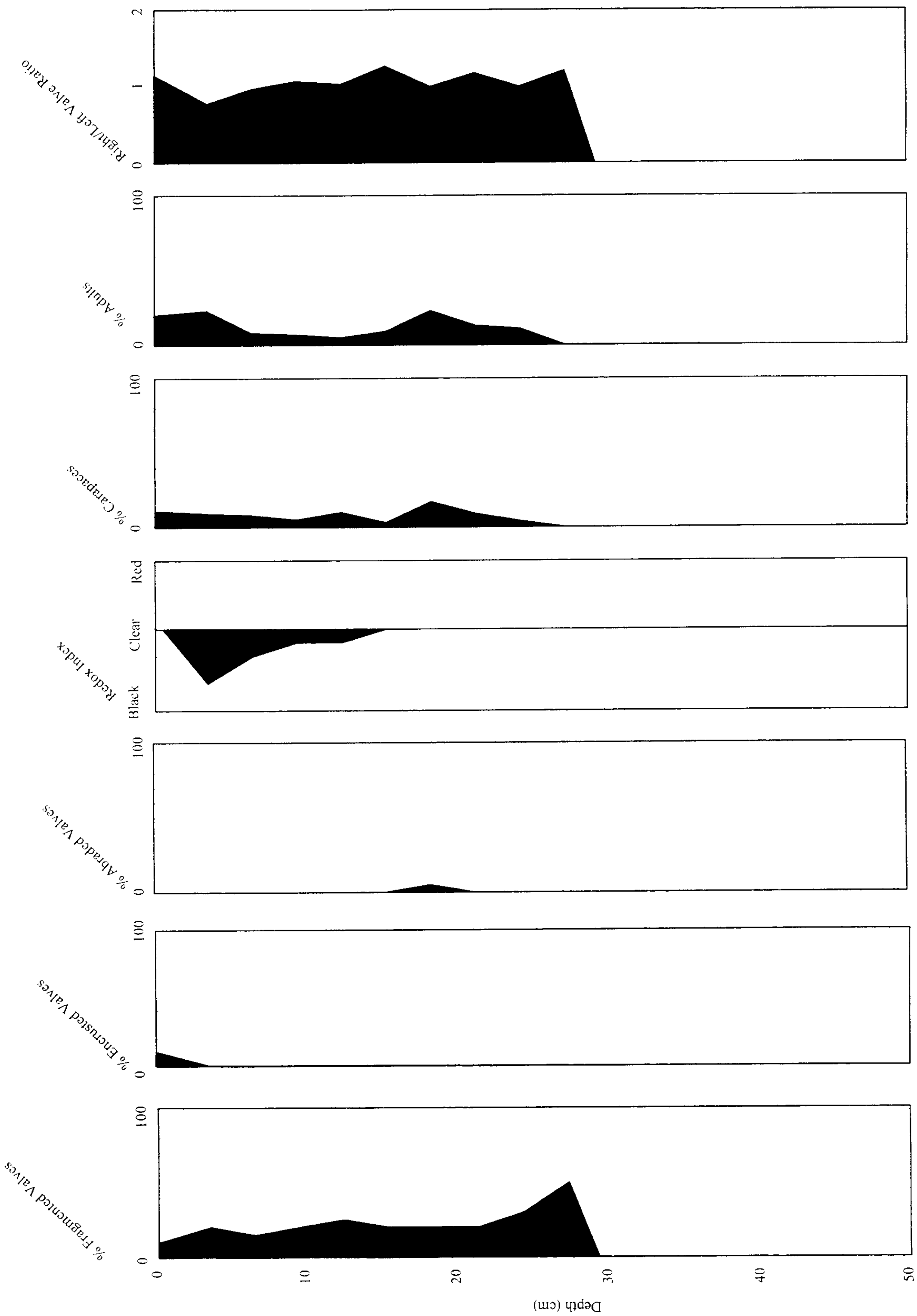


Fig. 3.20c

Core LT-98-2M



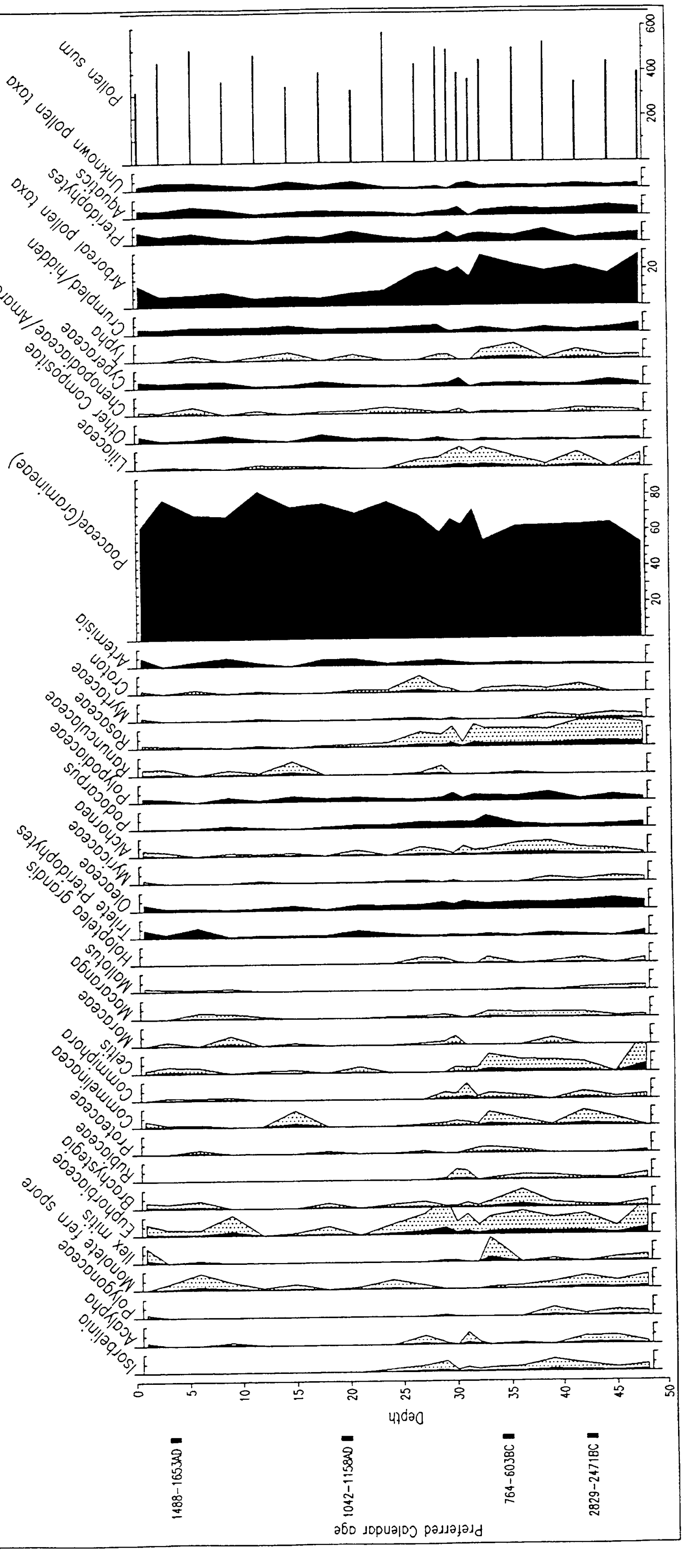
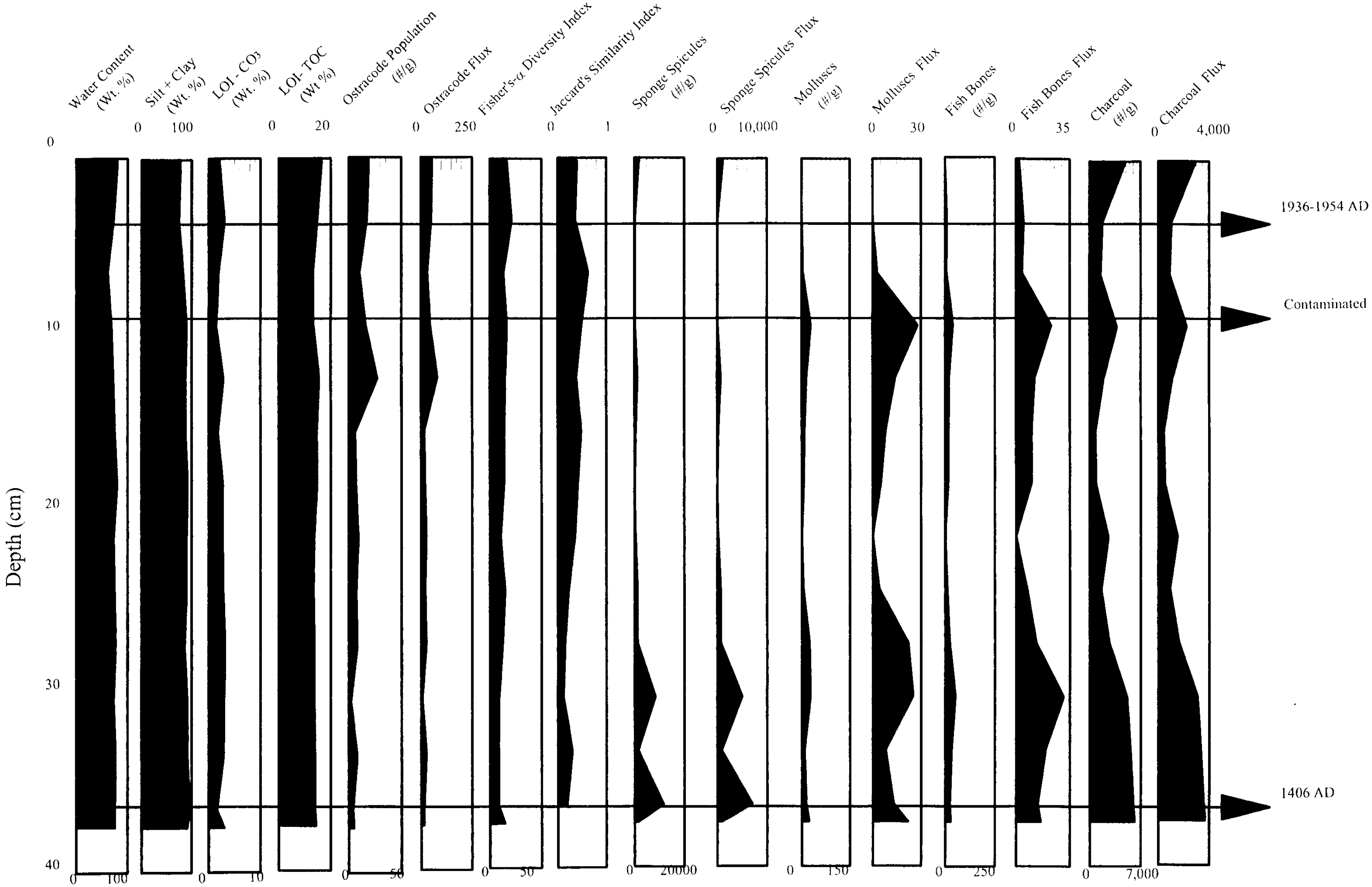


Fig.3.20.d
Pollen Diagram for Core LT-98-2M (Lubulungu River Delta)
Analyst: Emma Msaky
(Shaded portion indicates 5X exaggeration)

Core LT-98-12M

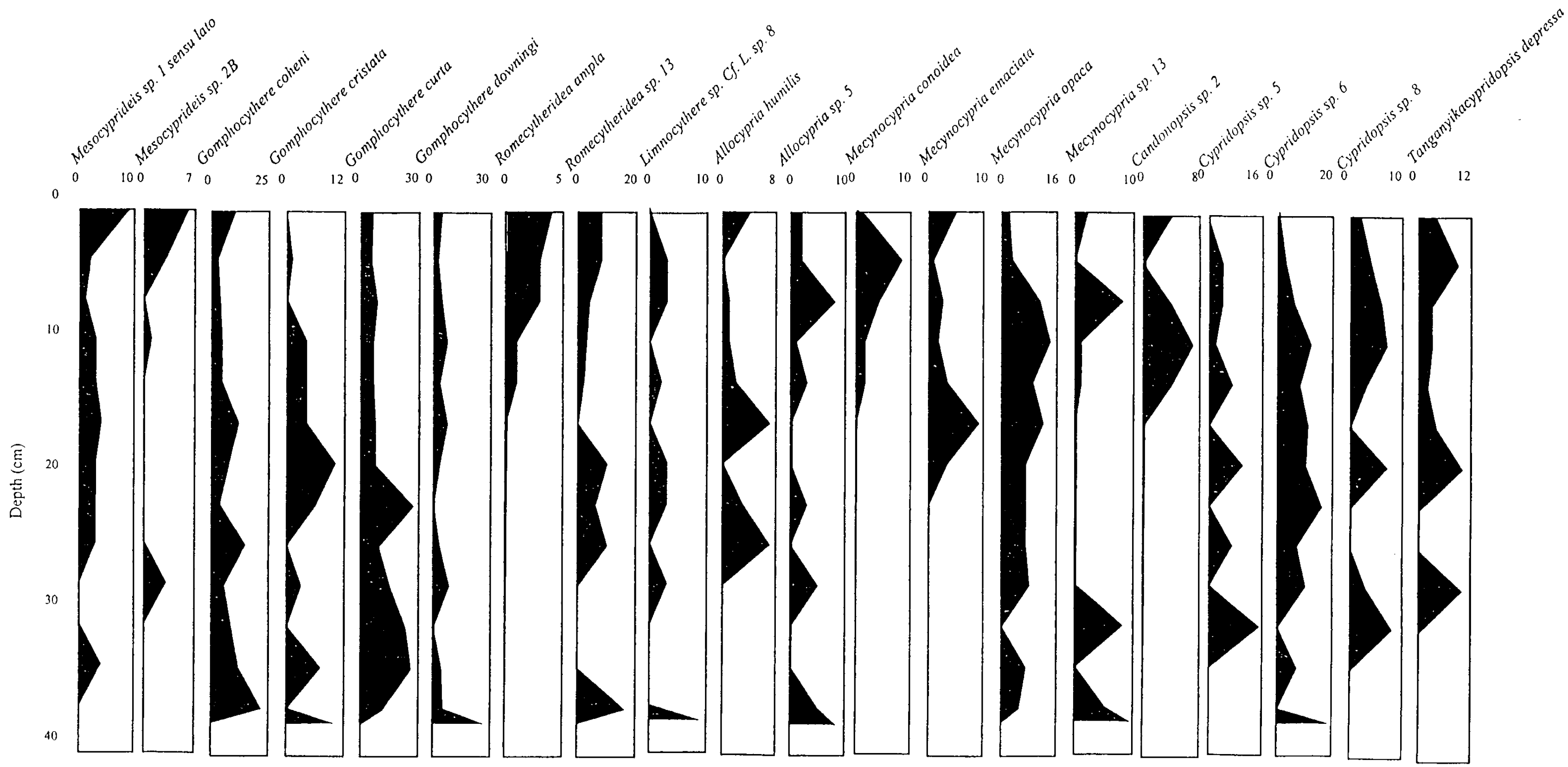
Fig. 3.21a



Core LT-98-12M

Fig. 3.21b(i)

Common Ostracode Species



Core LT-98-12M

Fig. 3.21b(ii)

Rare Ostracode Species

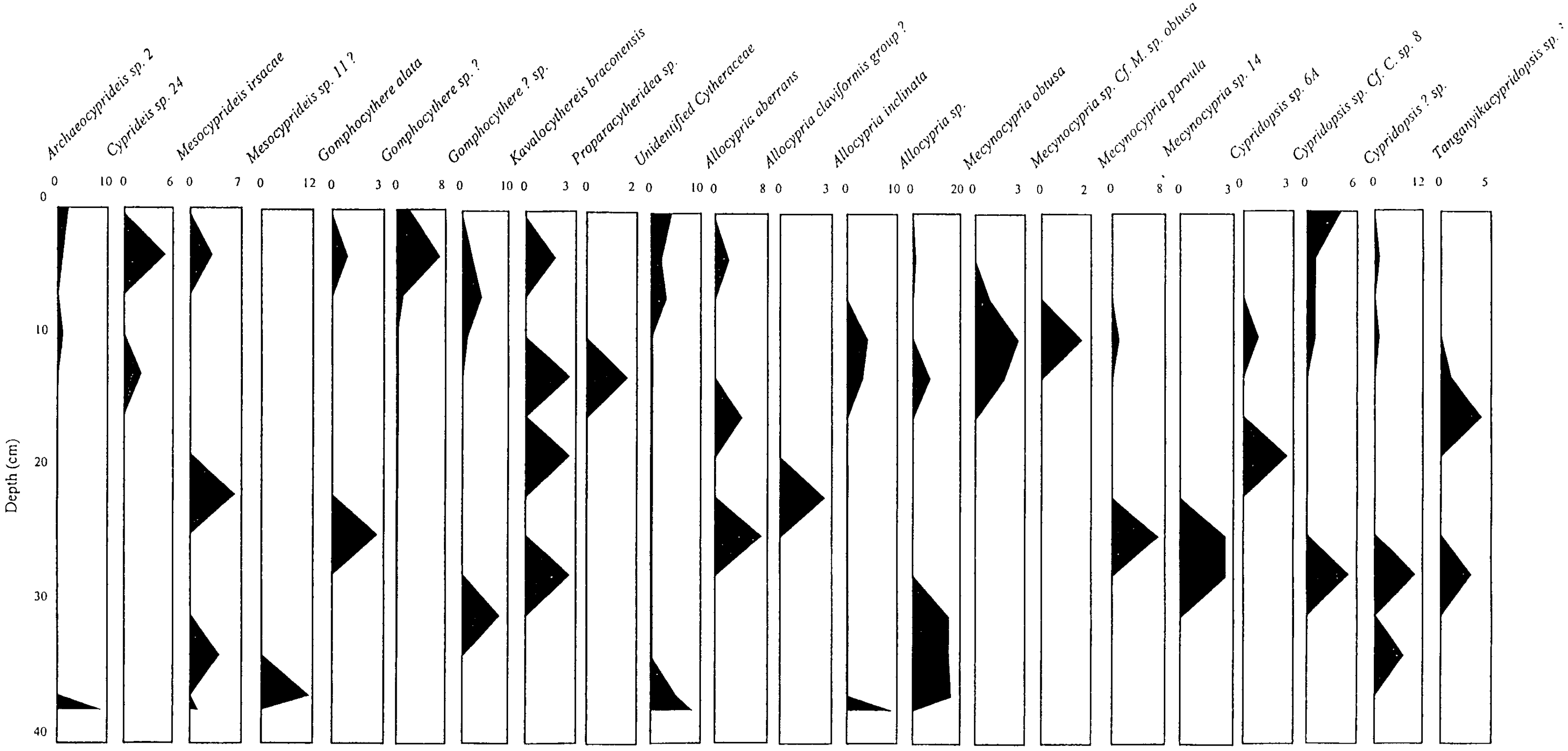
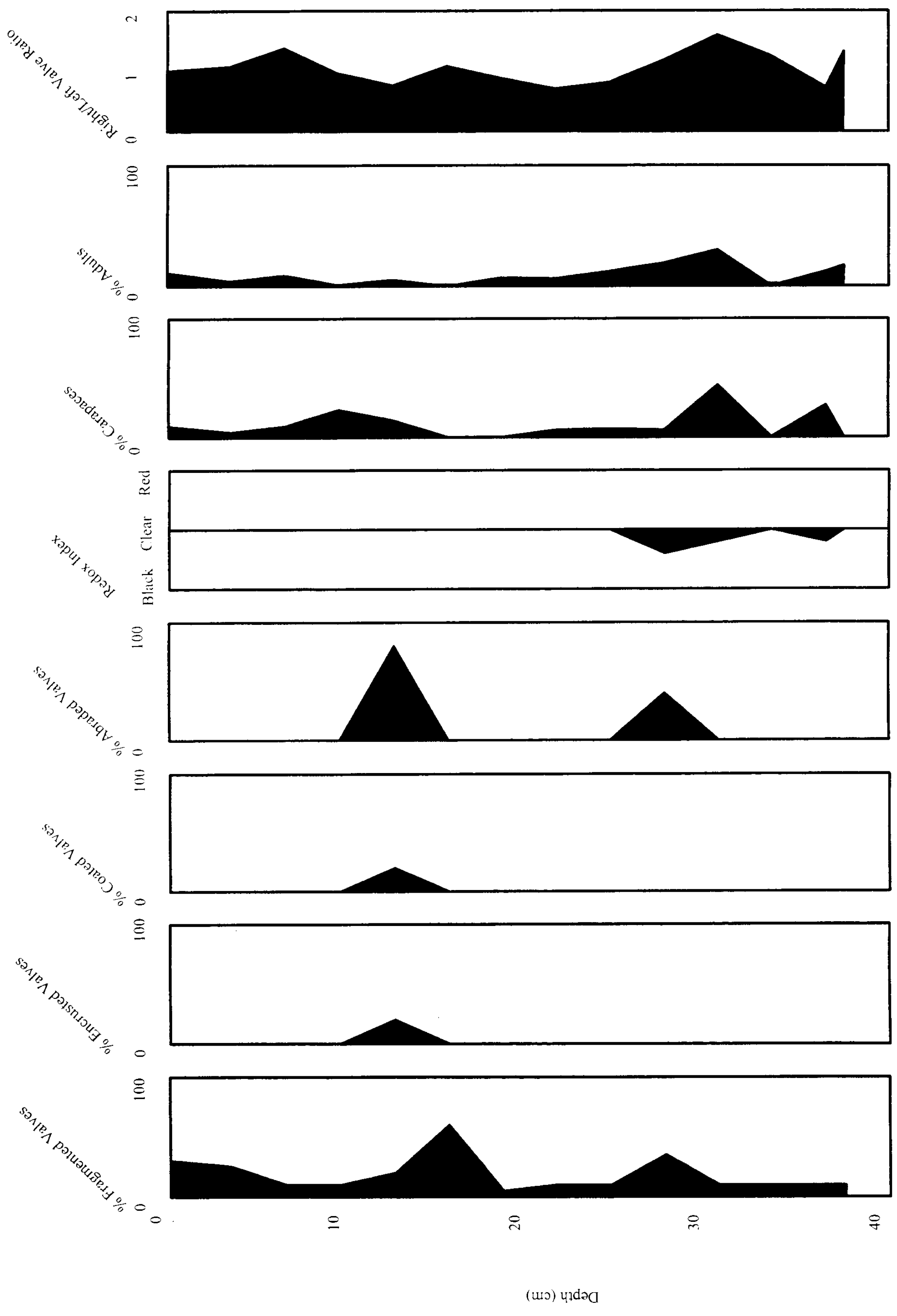


Fig. 3.21c

Core LT-98-12M



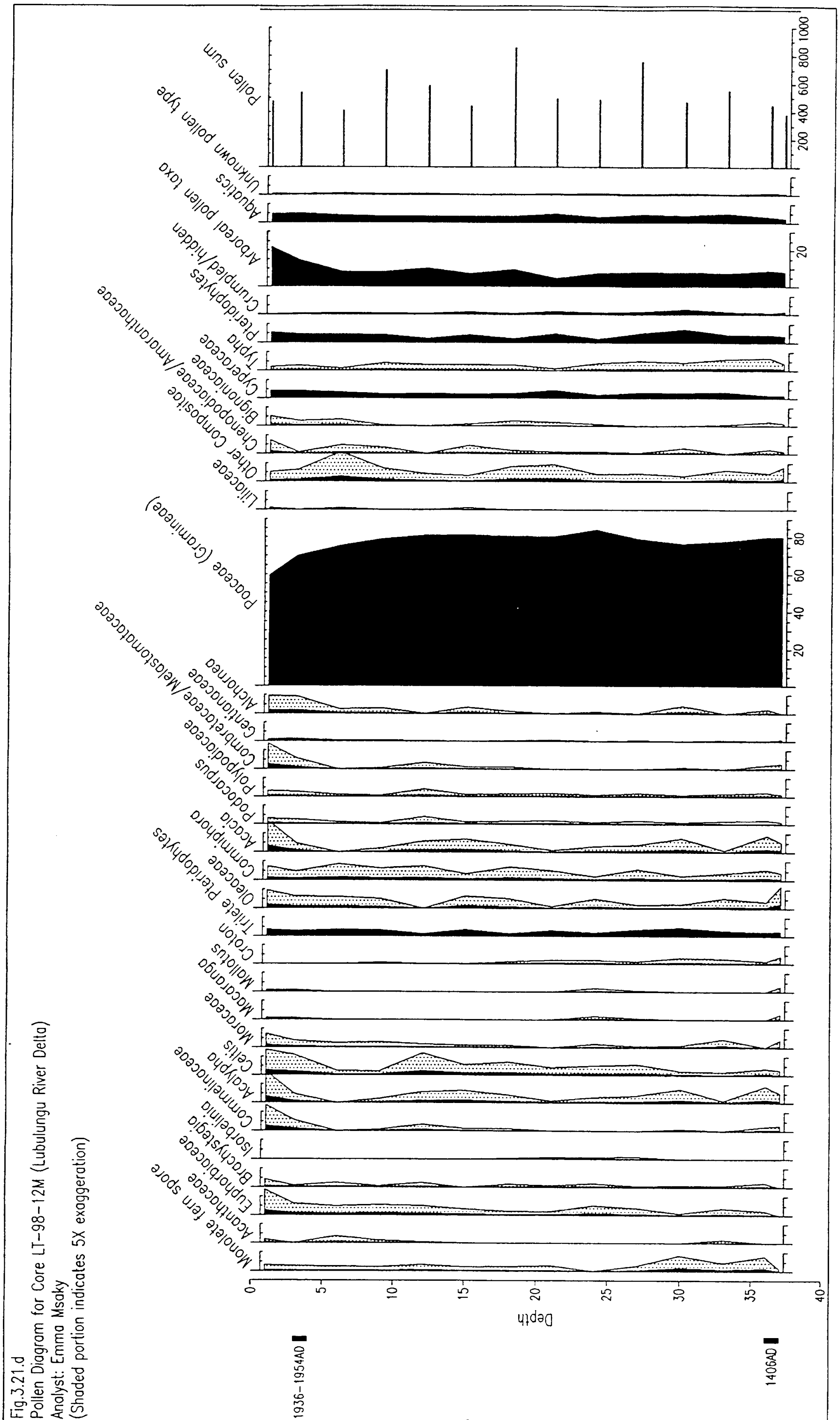
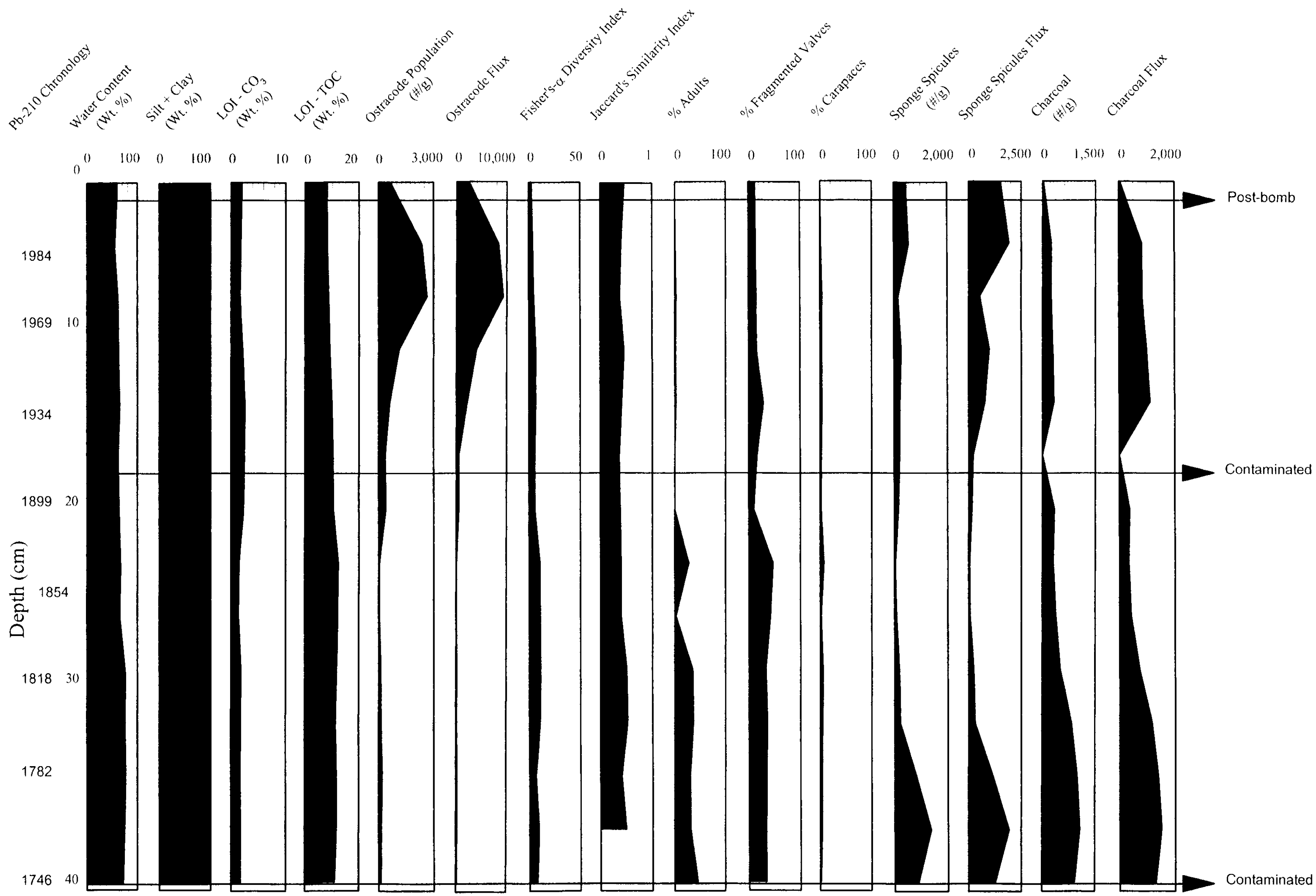


Fig.3.21.d
Pollen Diagram for Core LT-98-12M (Lubulungu River Delta)
Analyst: Emma Msaky
(Shaded portion indicates 5X exaggeration)

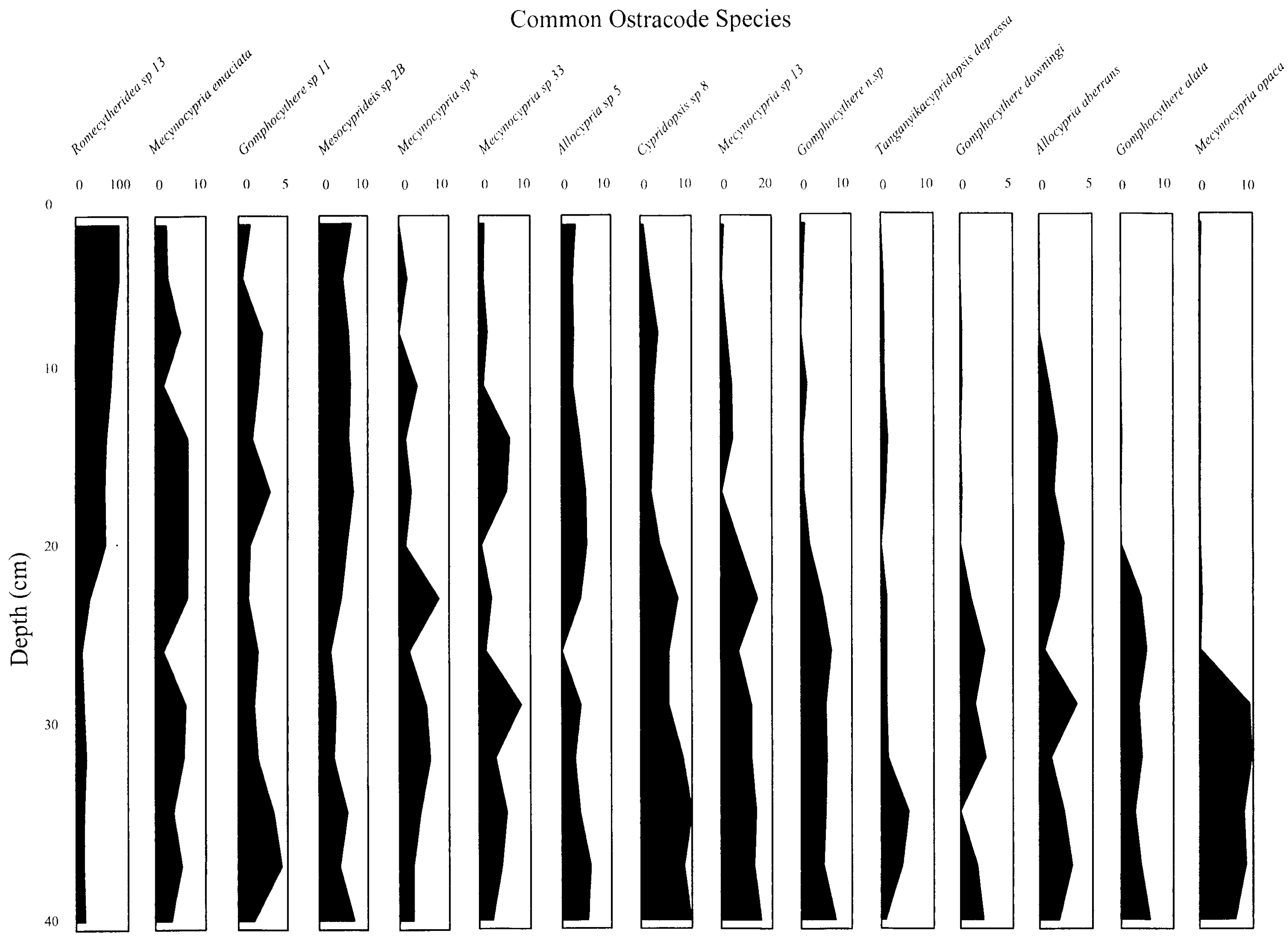
Core LT-98-18M

Fig. 3.22a



Core LT-98-18M

Fig. 3.22b



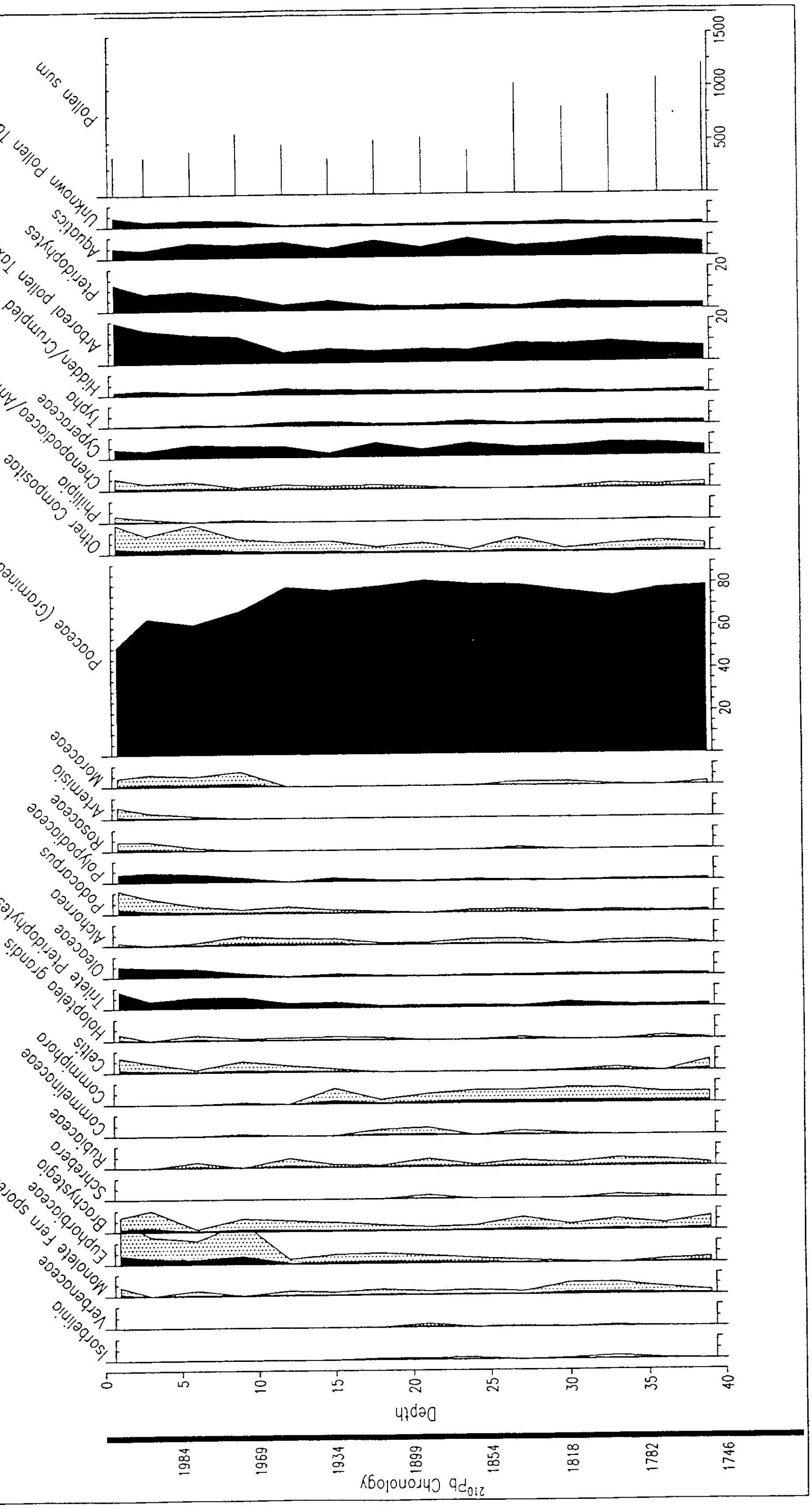
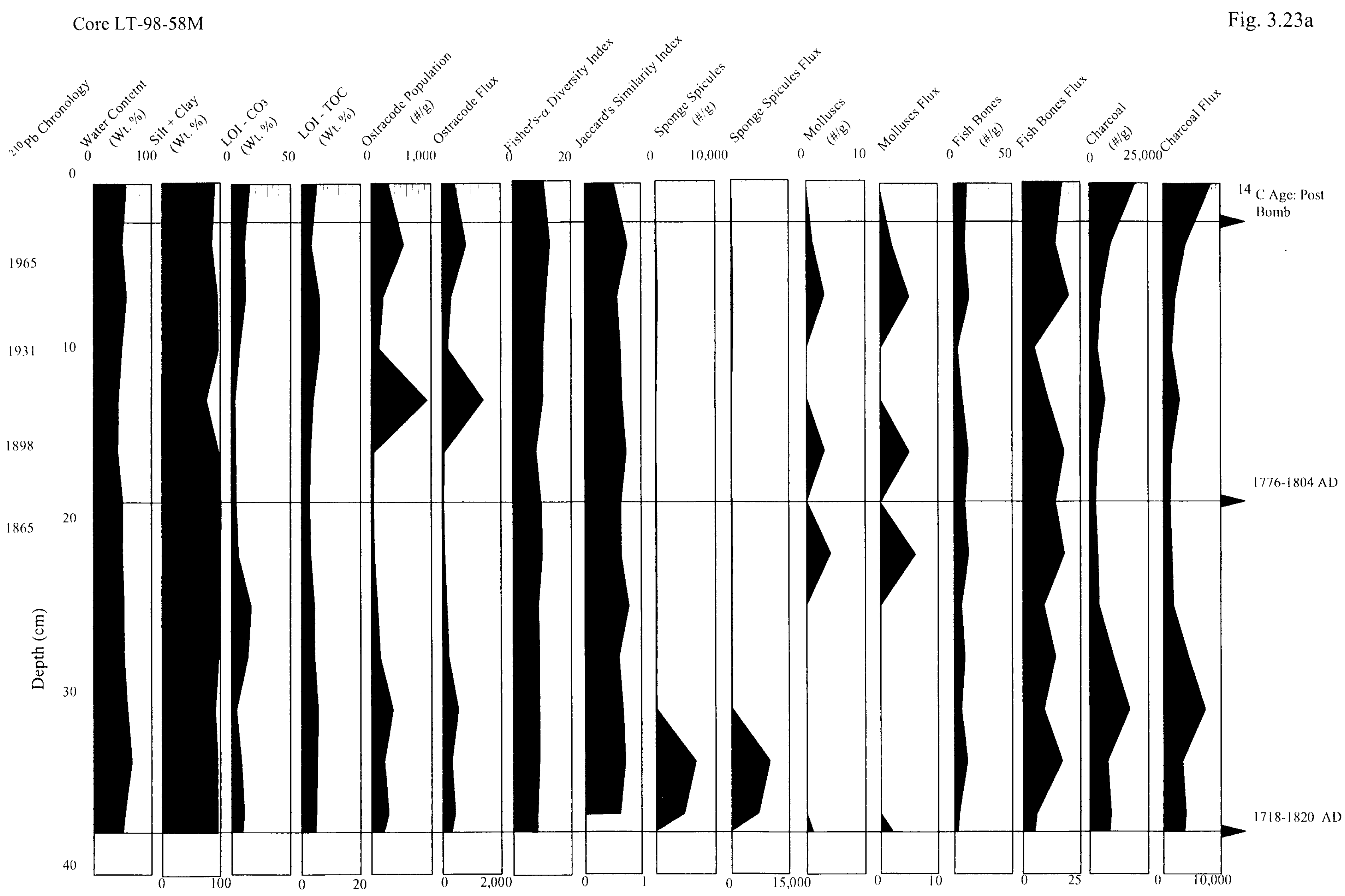


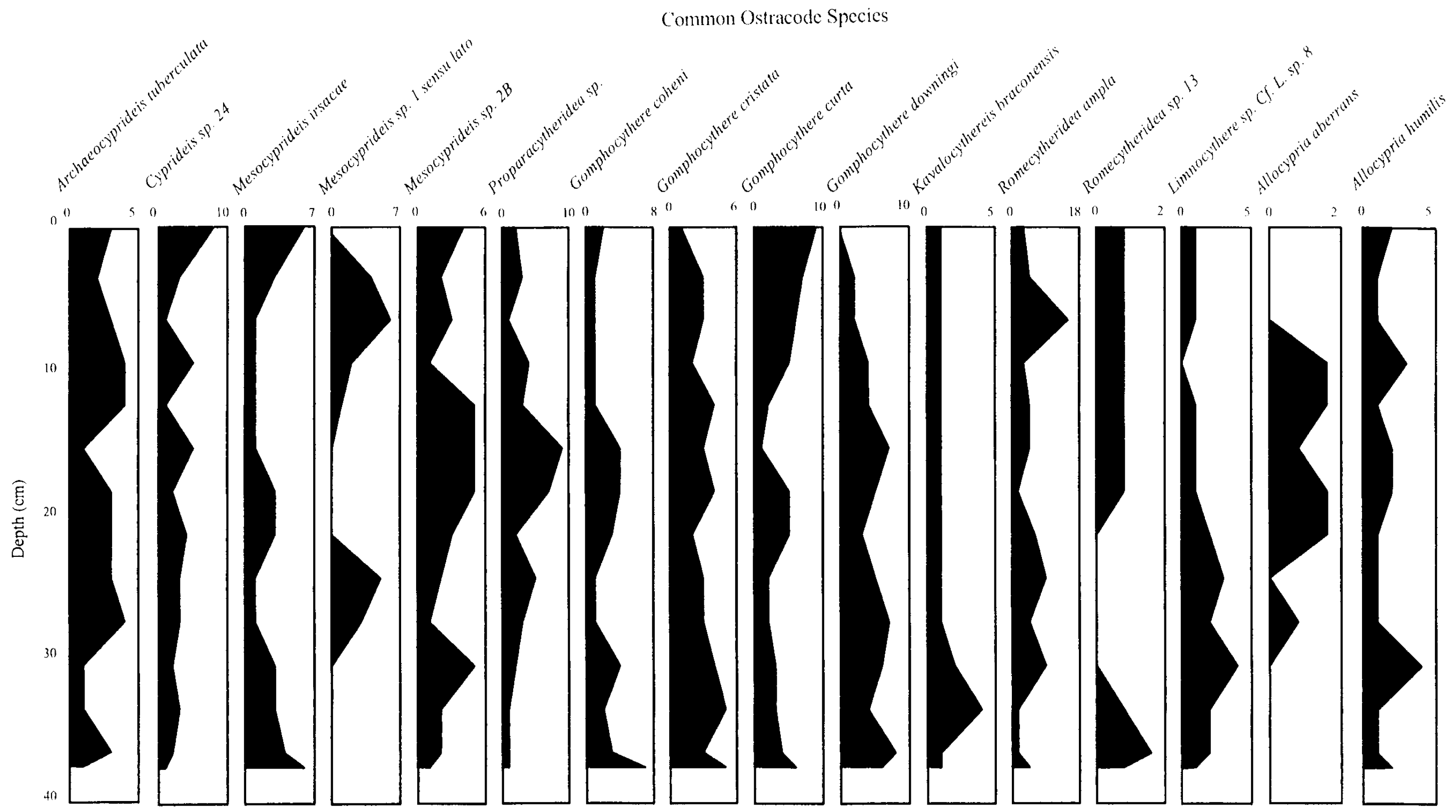
Fig.3.22.c
Pollen Diagram for Core LT-98-18M (Kabesi River Delta)
Analyst: Emma Msaky
(Shaded portion indicates 5X exaggeration)



Core LT-98-58M
Fig. 3.23a
210Pb Chronology
Water Contetnt (Wt. %)
Silt + Clay (Wt. %)
LOI - CO3 (Wt. %)
LOI - TOC (Wt. %)
Ostracode Population (#/g)
Ostracode Flux
Fisher's-α Diversity Index
Jaccard's Similarity Index
Sponge Spicules (#/g)
Sponge Spicules Flux
Molluscs (#/g)
Molluscs Flux
Fish Bones (#/g)
Fish Bones Flux
Charcoal (#/g)
Charcoal Flux
14 C Age: Post Bomb
1776-1804 AD
1718-1820 AD
1965
1931
1898
1865
Depth (cm)
0
10
20
30
40

Core LT-98-58M

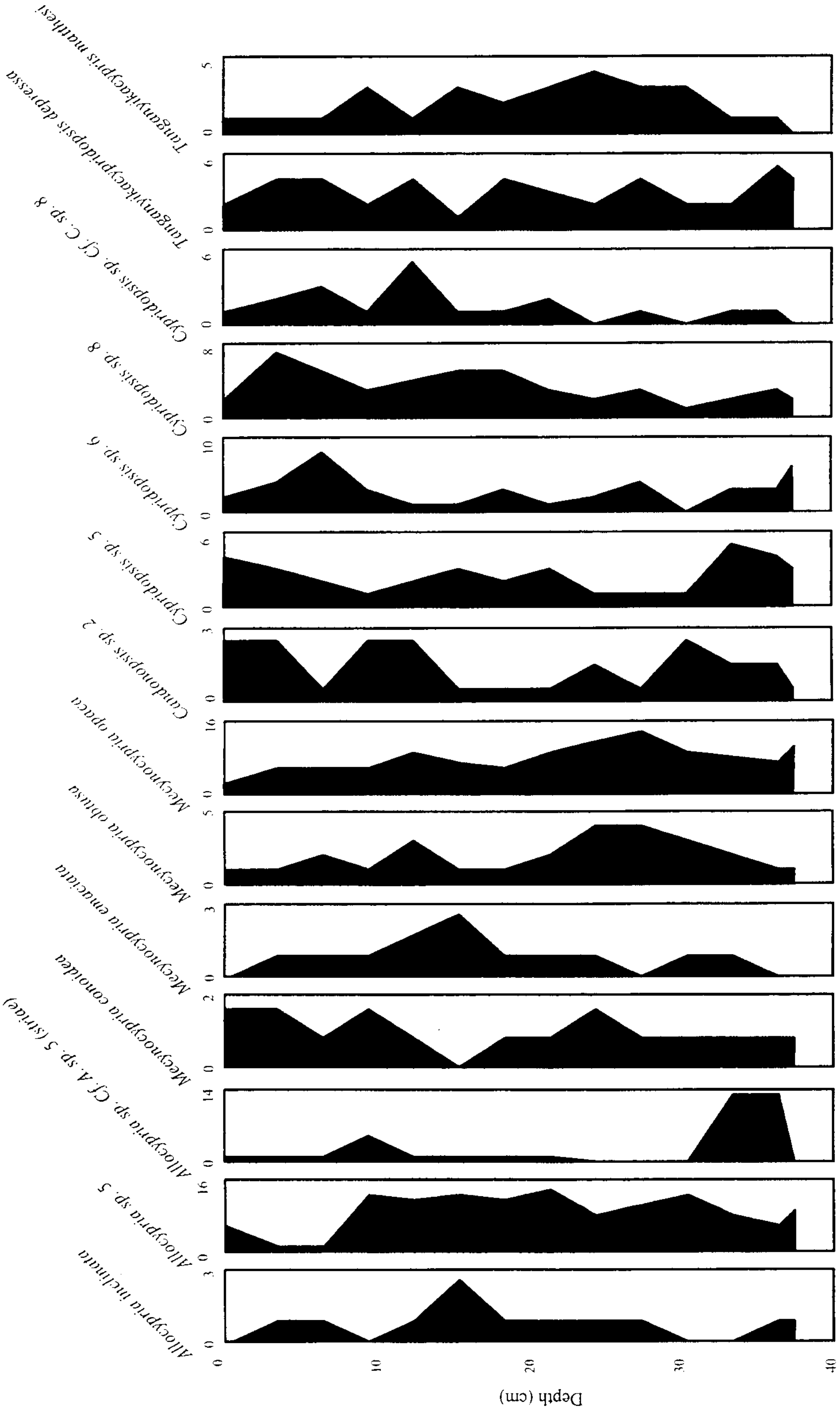
Fig. 3.23b(i)



Core LT-98-58M

Common Ostracode Species

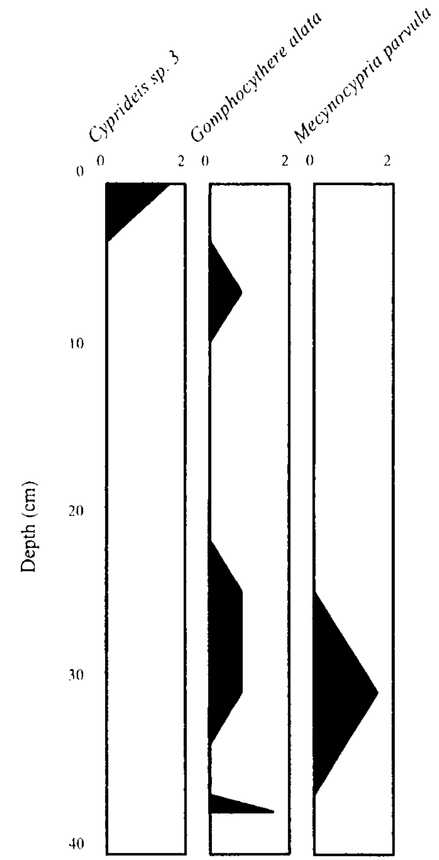
Fig. 3.23b(ii)



Core LT-98-58M

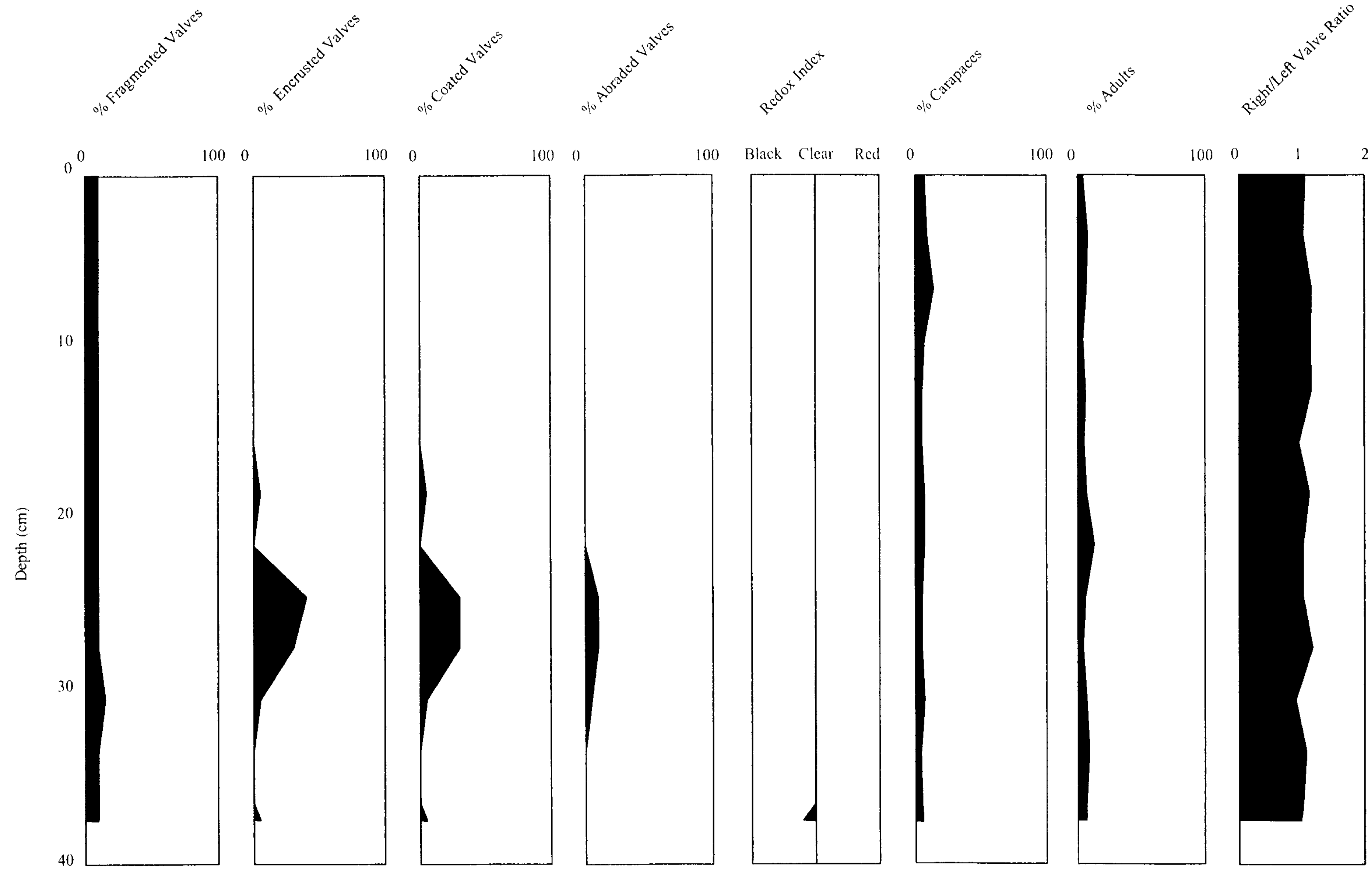
Fig. 3.23b(iii)

Rare Ostracode Species



Core LT-98-58M

Fig. 3.23c



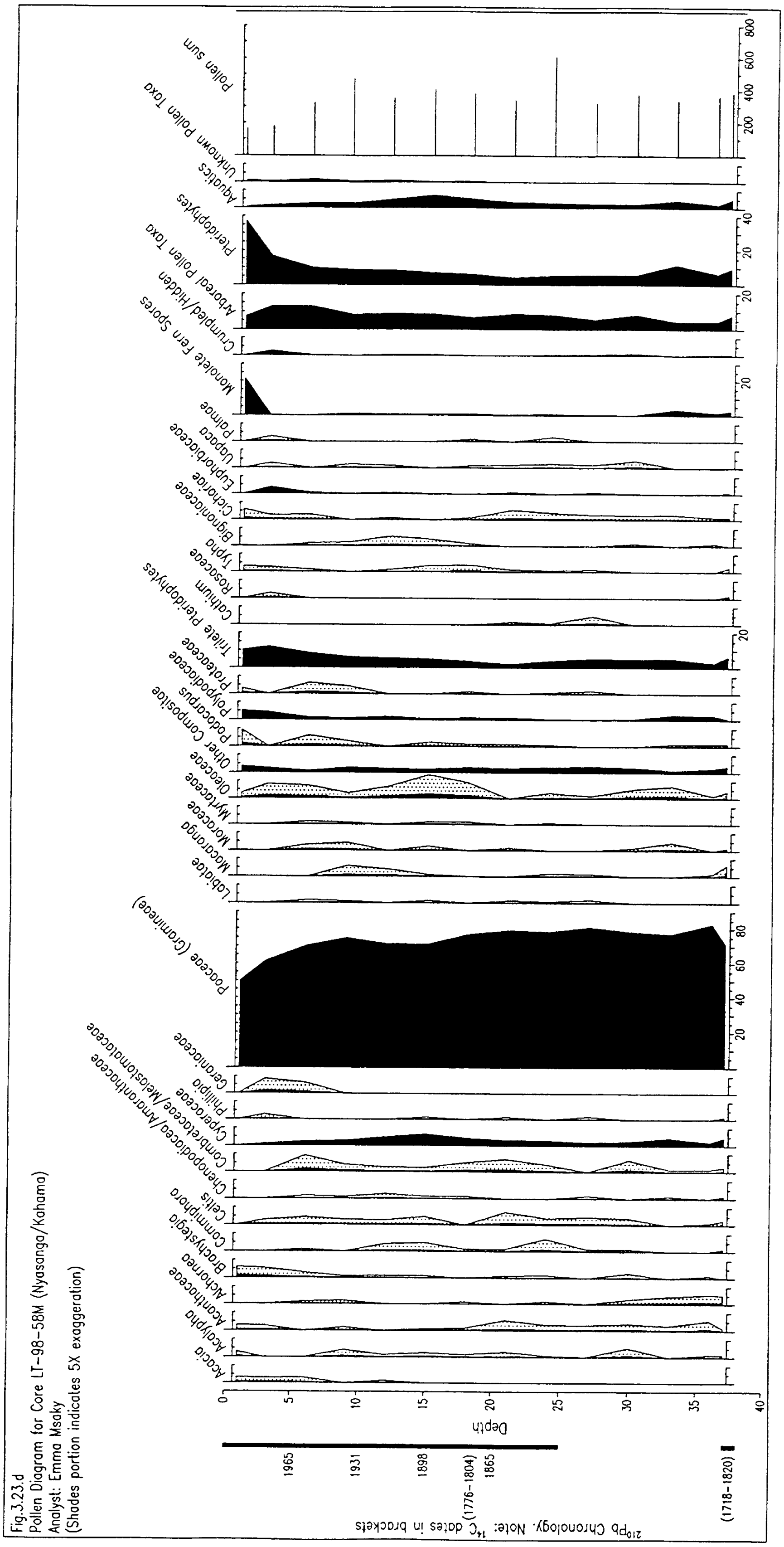
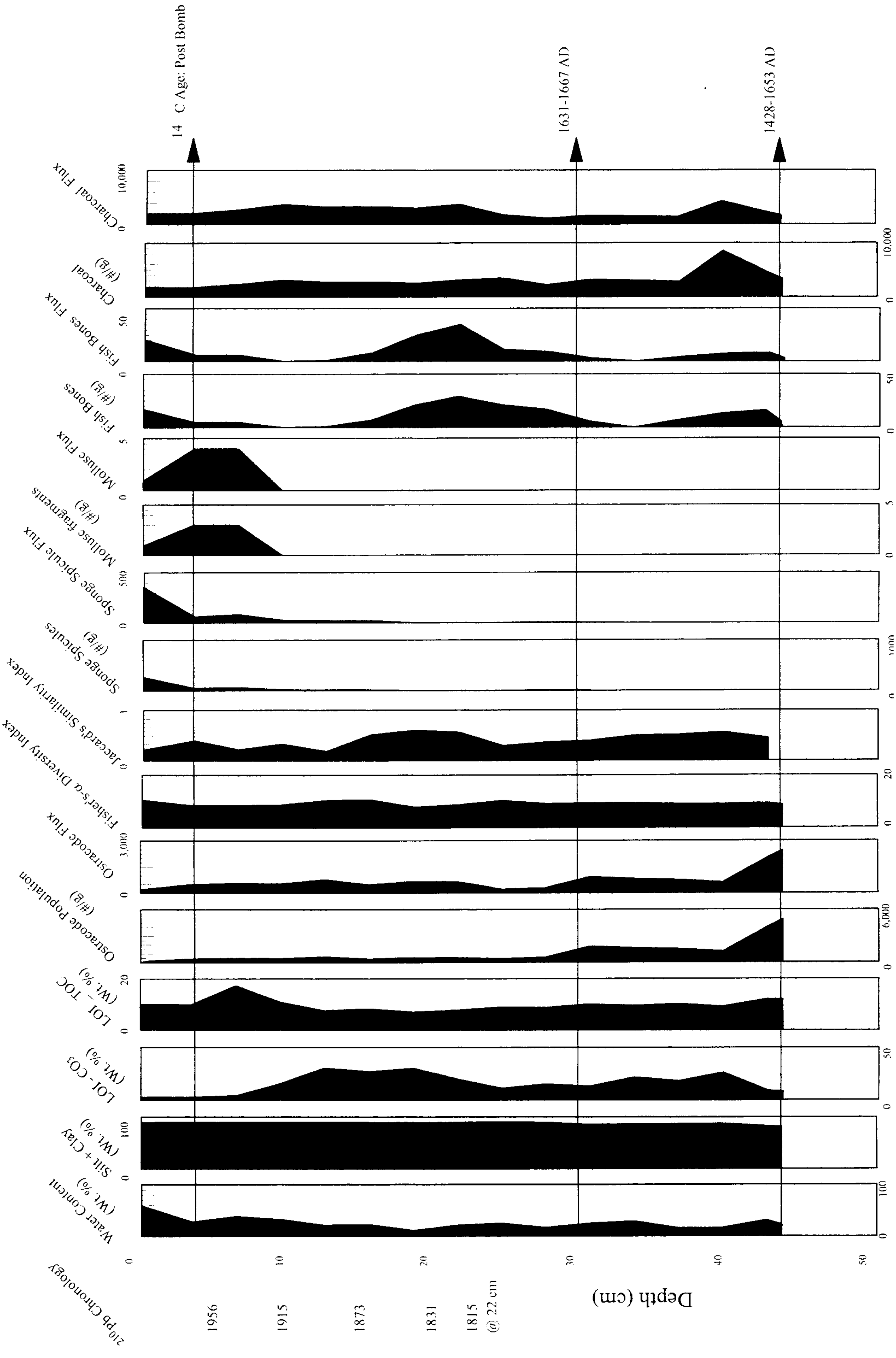


Fig.3.23.d
Pollen Diagram for Core LT-98-58M (Nyasanga/Kahama)
Analyst: Emma Msaky
(Shades portion indicates 5X exaggeration)

Fig. 3.24a

Core LT-98-37M



Core LT-98-37M

Fig. 3.24b(i)

Common Ostracode Species

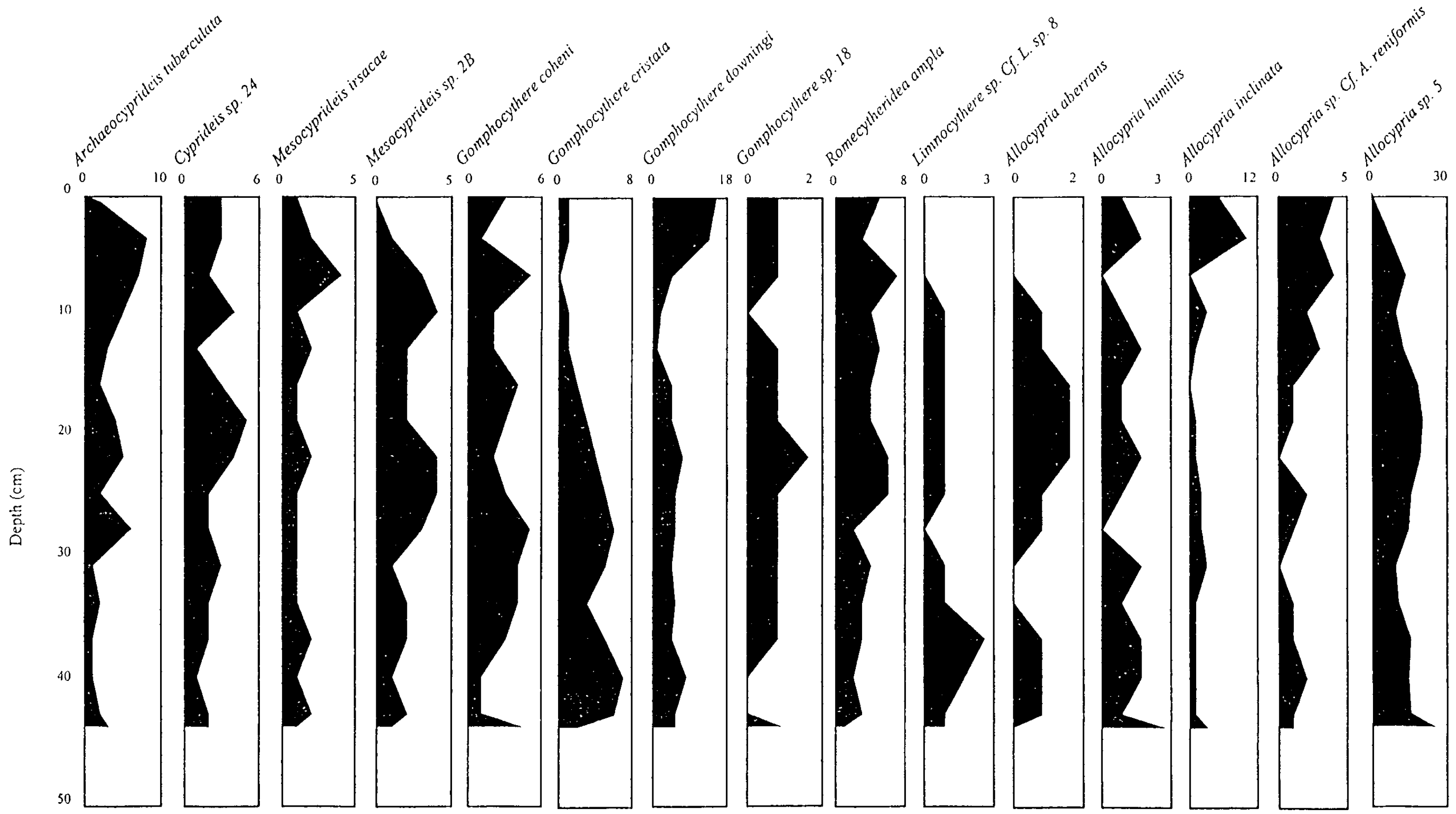
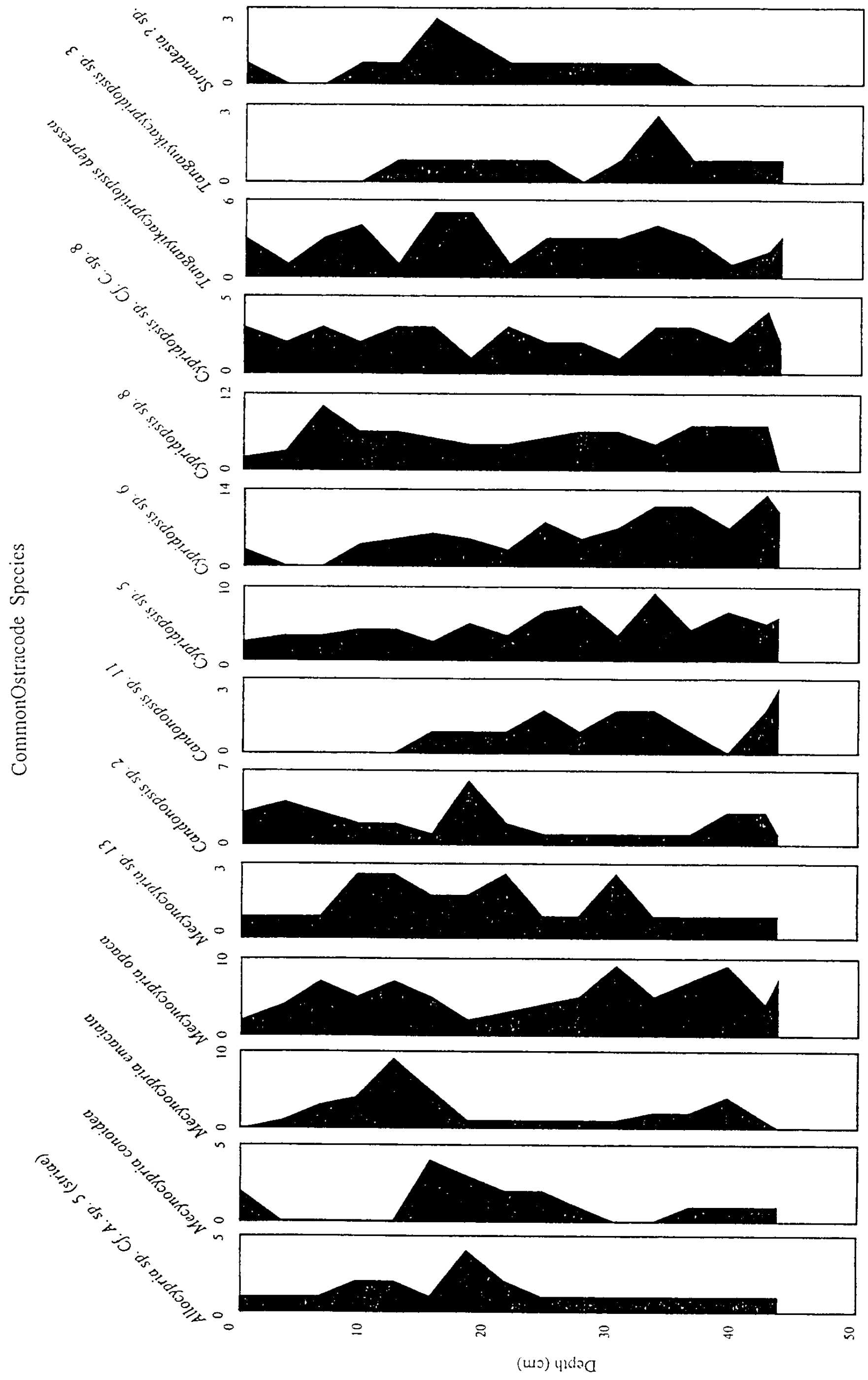


Fig. 3.24b(ii)



Core LT-98-37M

Fig. 3.24b(iii)

Rare Ostracode Species

Core LT-98-37M

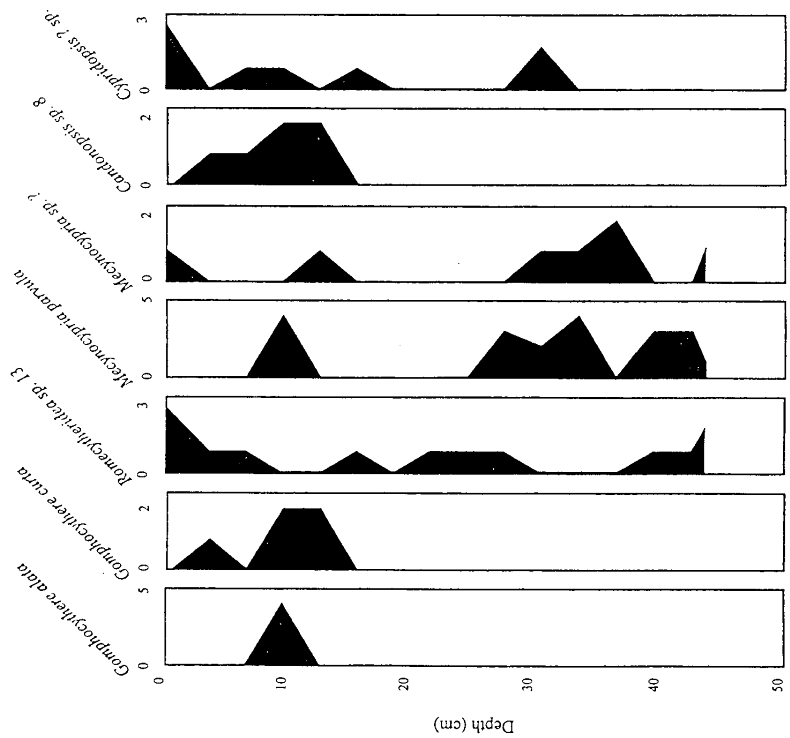


Fig. 3.24c

Core LT-98-37M

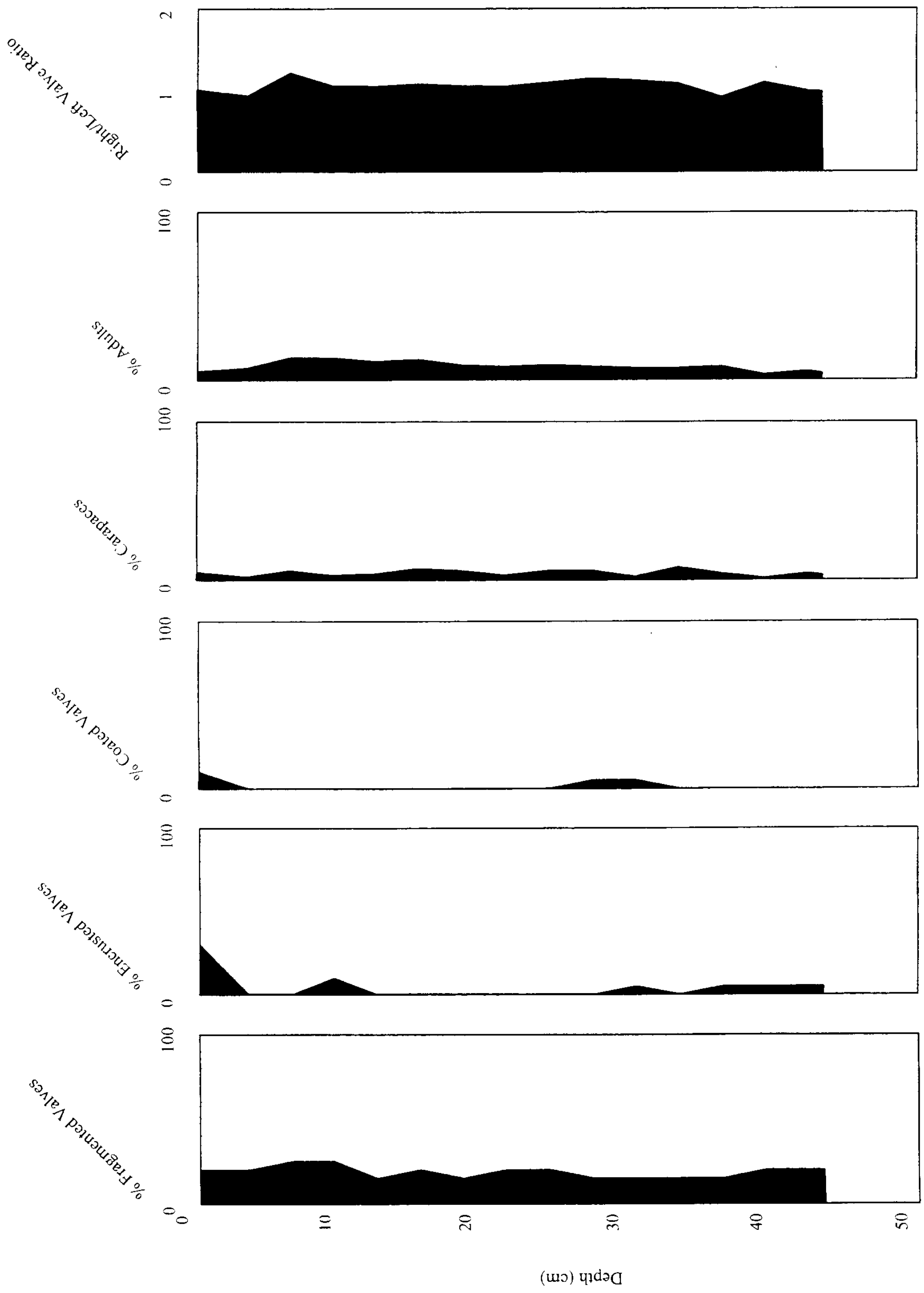
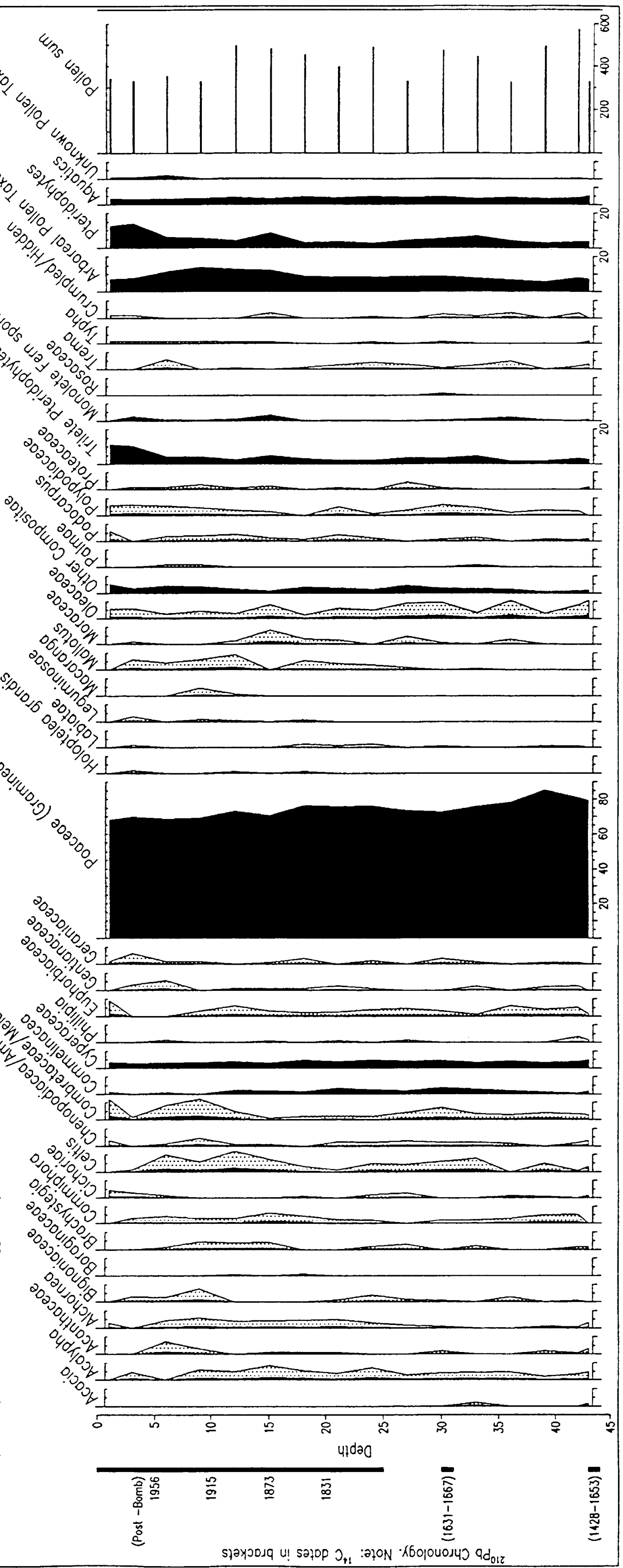
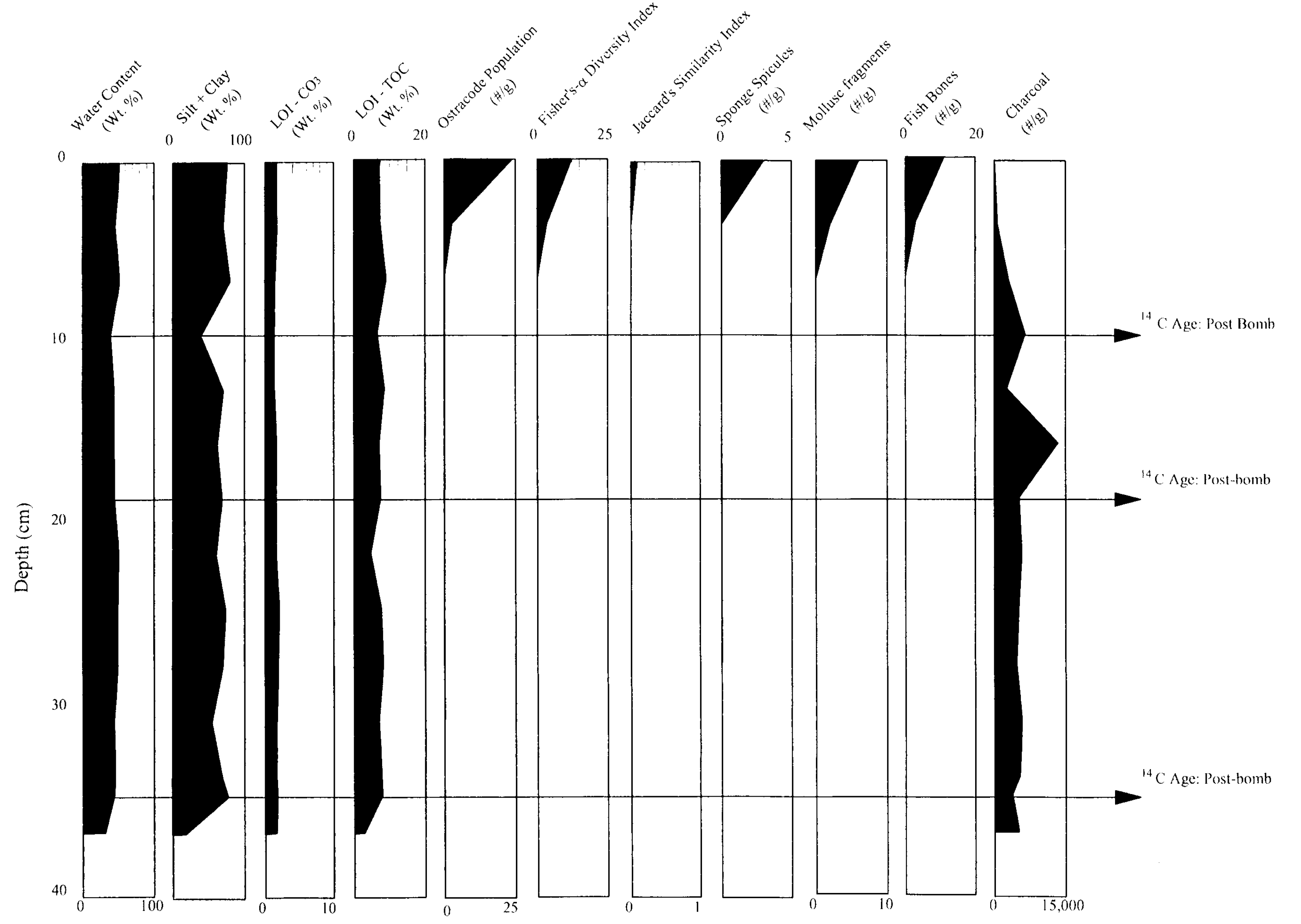


Fig.3.24.d
Pollen Diagram for Core LT-98-37M (Mwamgongo)
Analyst: Emma Msaky
(Shaded portion indicates 5X exaggeration)



Core LT-98-98M

Fig. 3.25a



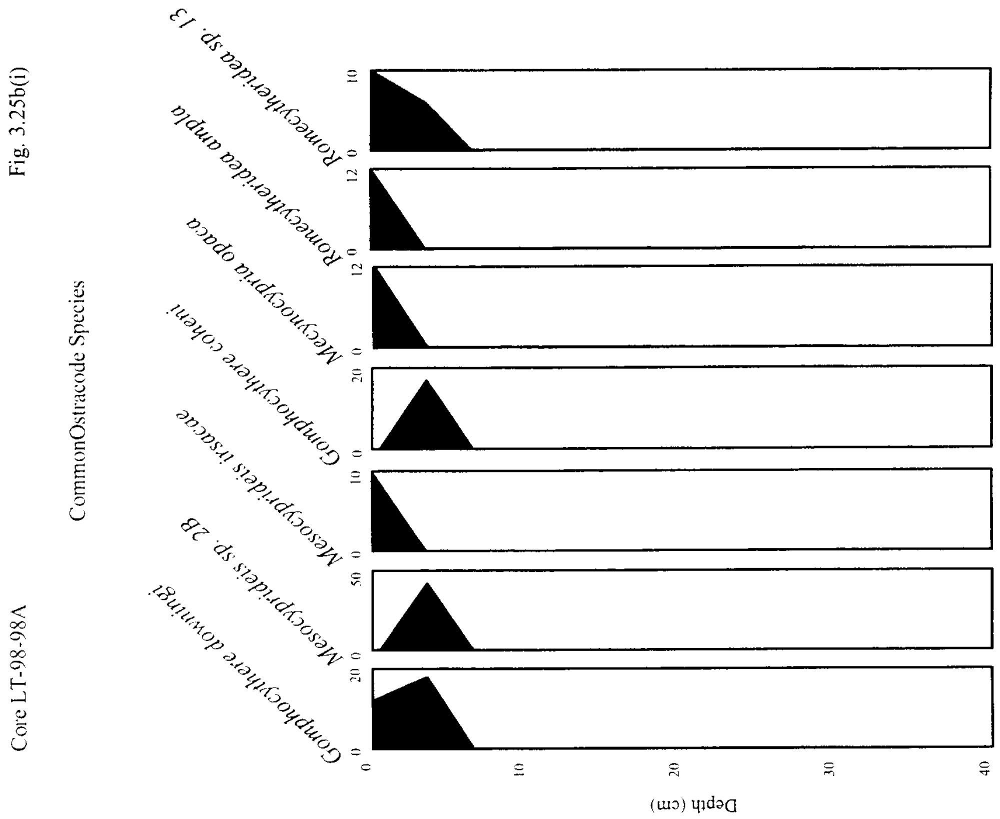
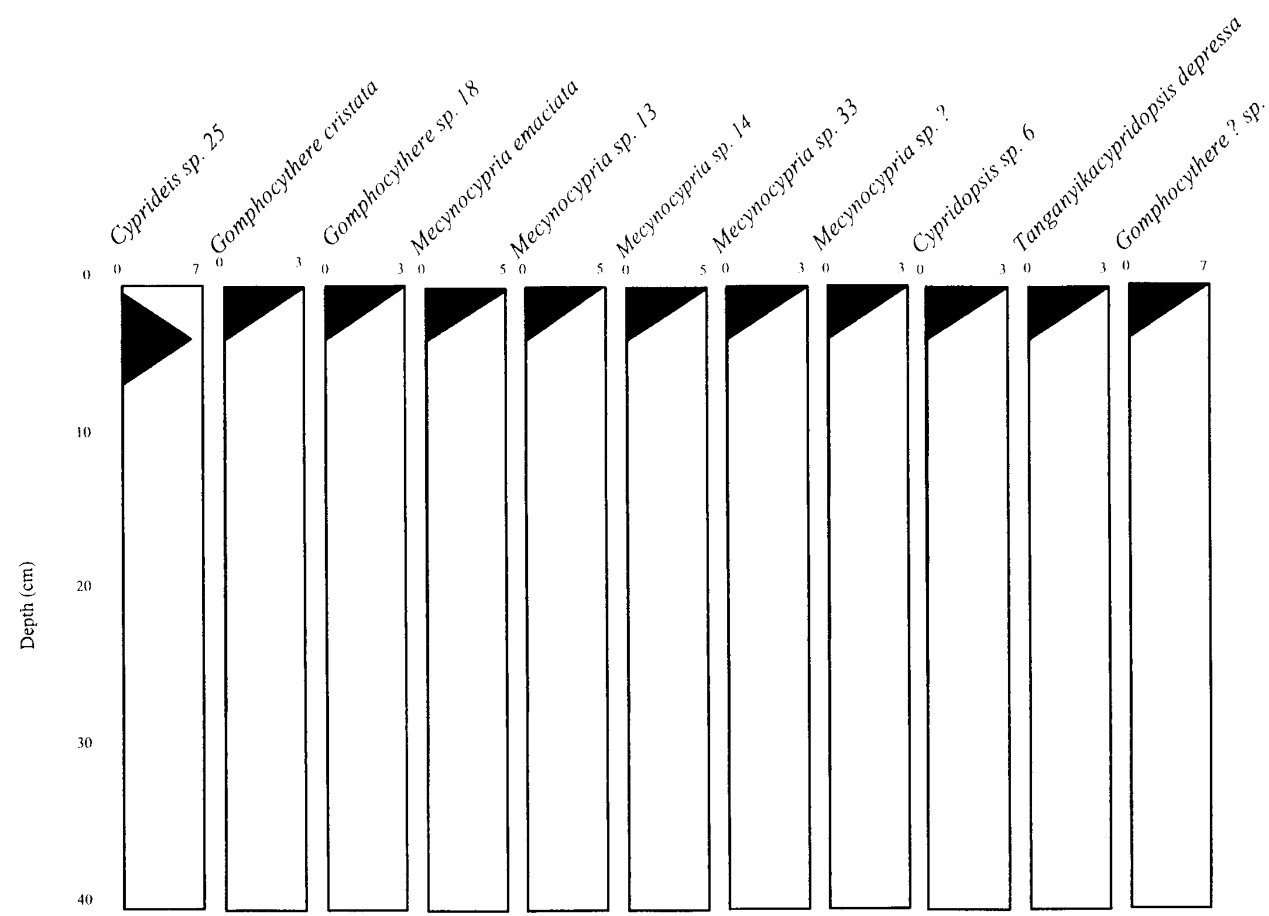


Fig. 3.25b(i)
Core LT-98-98A
CommonOstracode Species
Romecytheridea sp. 13
Romecytheridea ampla
Mecynocypria opaca
Gomphocythere coheni
Mesocyprideis irsacae
Mesocyprideis sp. 2B
Gomphocythere downingi
Depth (cm)

Core LT-98-98A

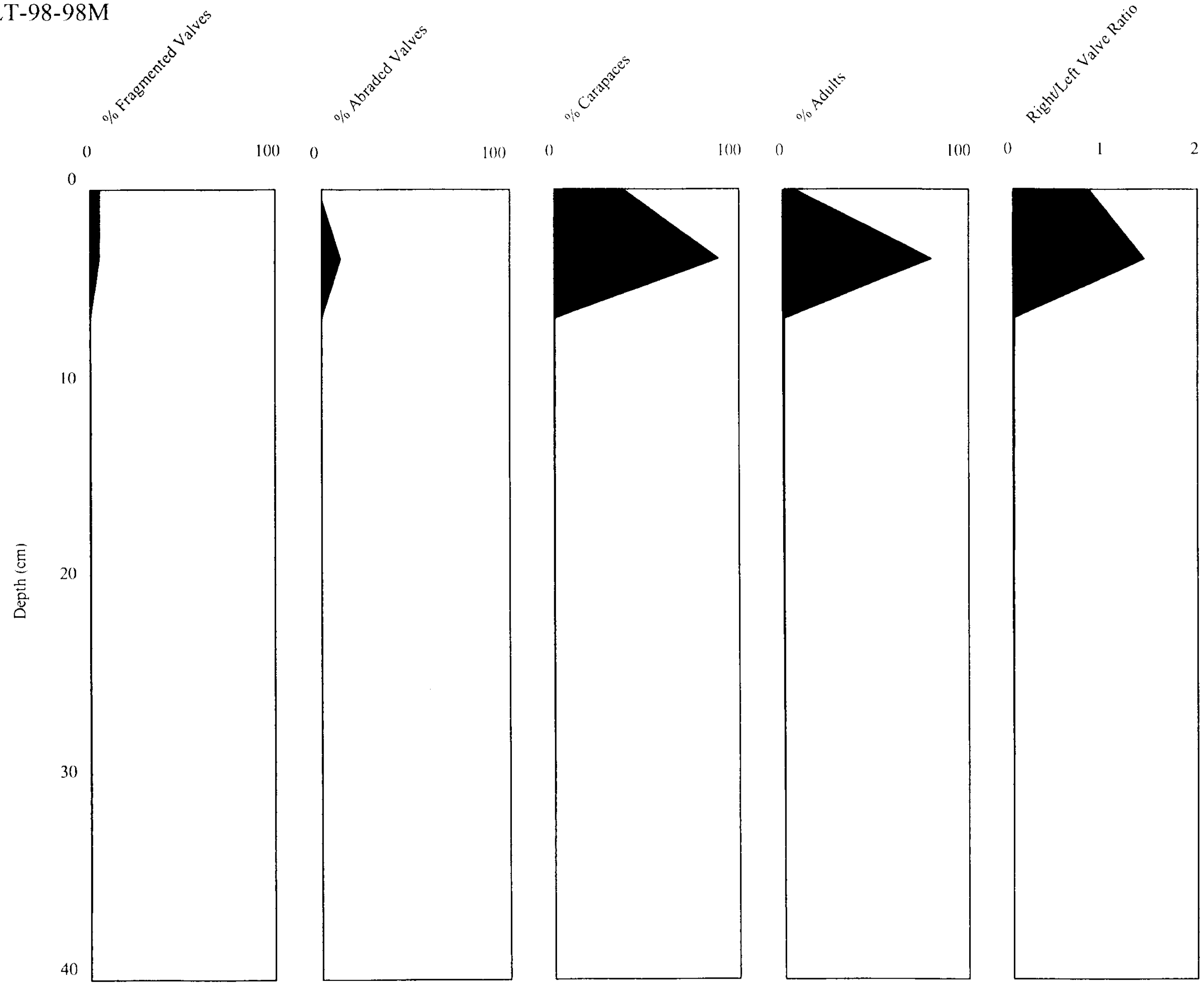
Fig. 3.25b(ii)

Rare Ostracode Species



Core LT-98-98M

Fig. 3.25c



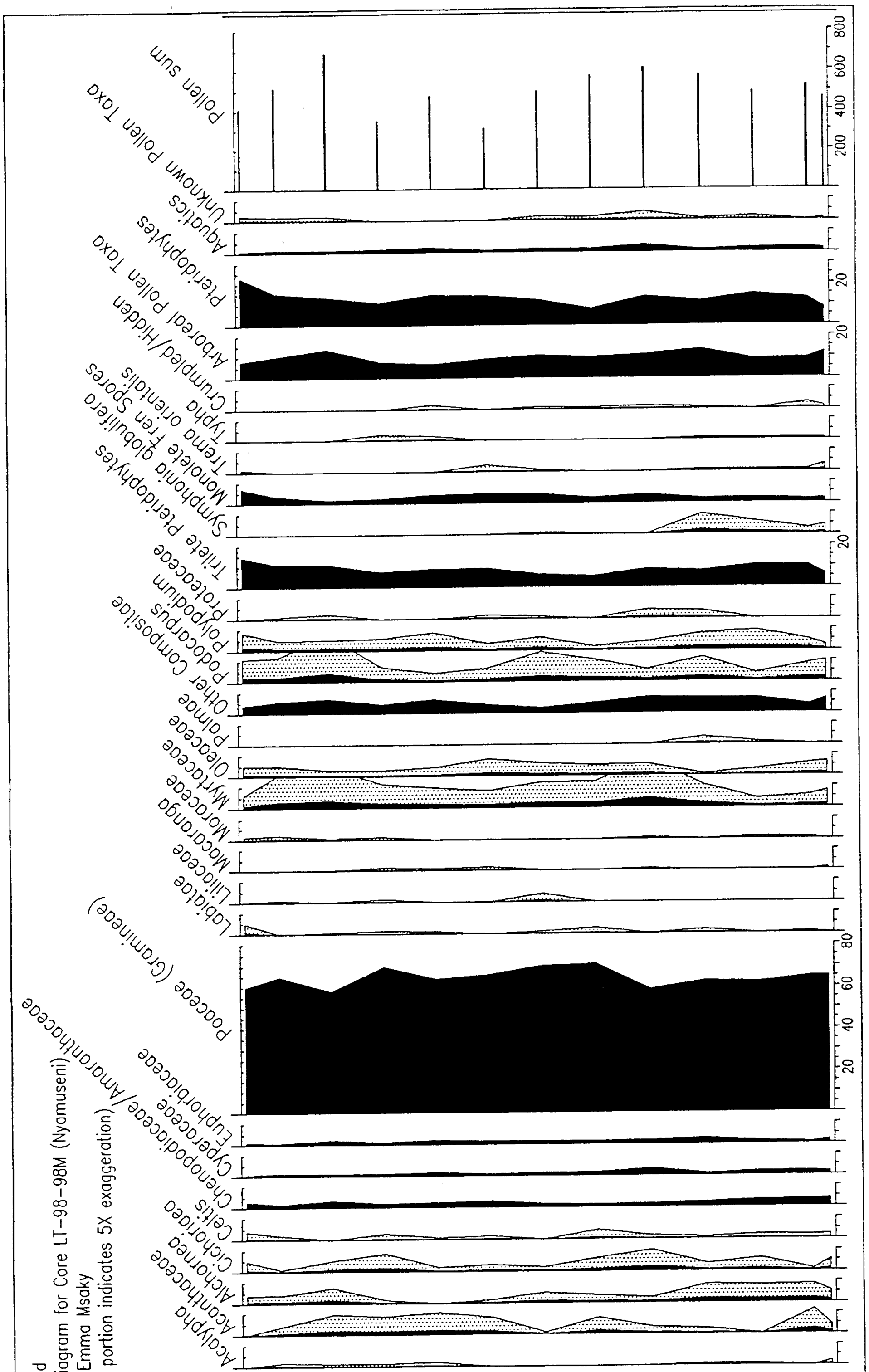
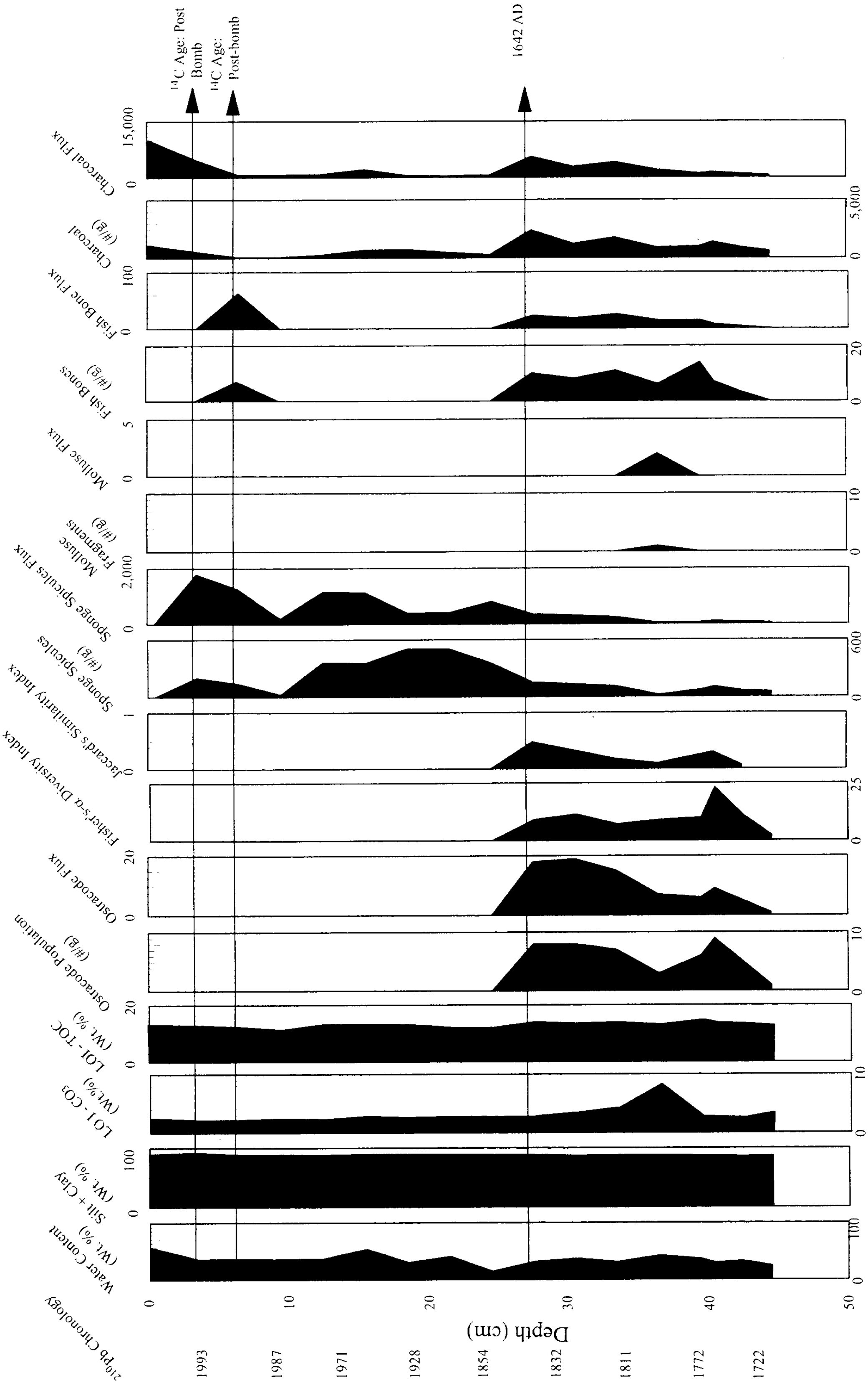


Fig.3.25.d
Pollen Diagram for Core LT-98-98M (Nyamuseni)
Analyst: Emma Msaky
(Shaded portion indicates 5X exaggeration)

Fig. 3.26a

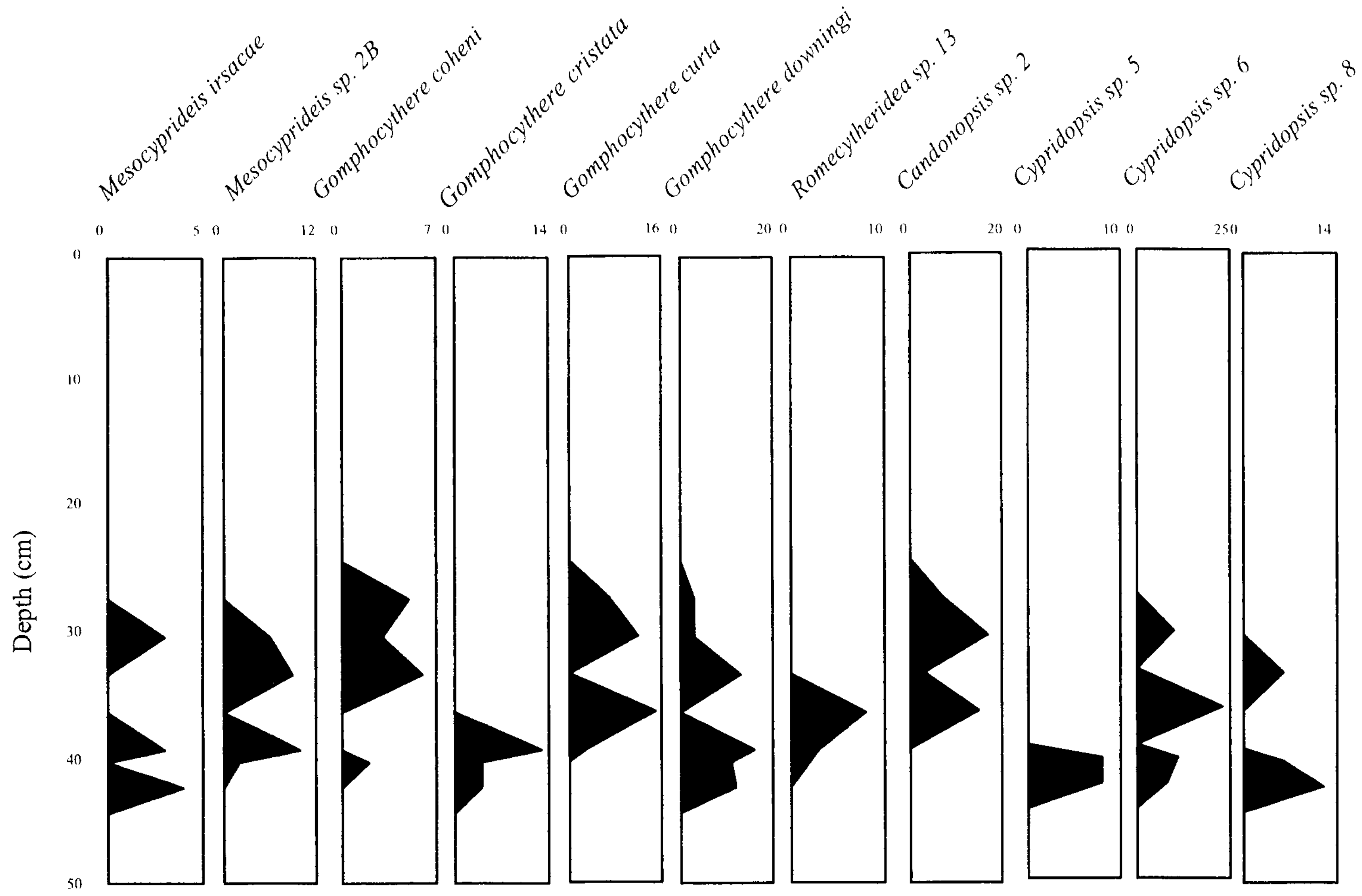
Core LT-98-82M



Core LT-98-82M

Fig. 3.26b(i)

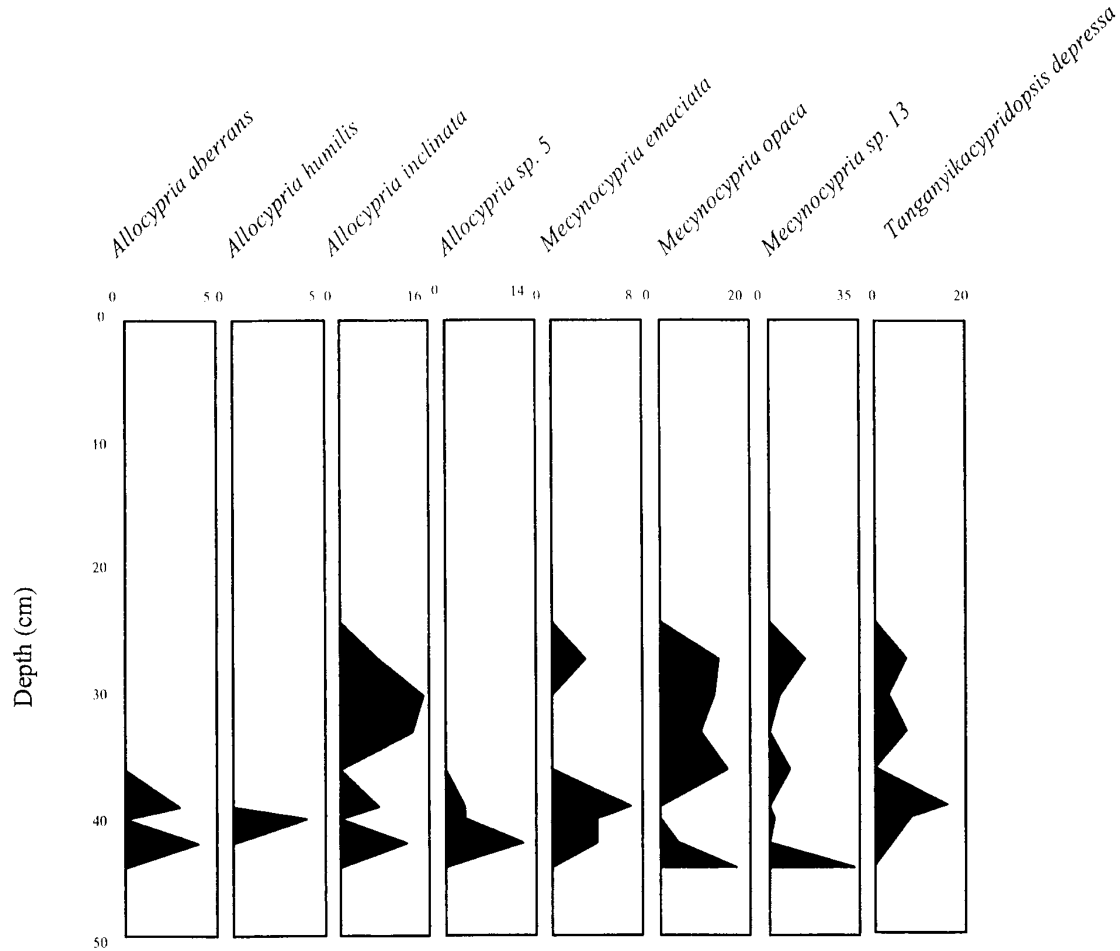
CommonOstracode Species



Core LT-98-82M

Fig. 3.26b(ii)

CommonOstracode Species



Core LT-98-82M

Fig. 3.26b(iii)

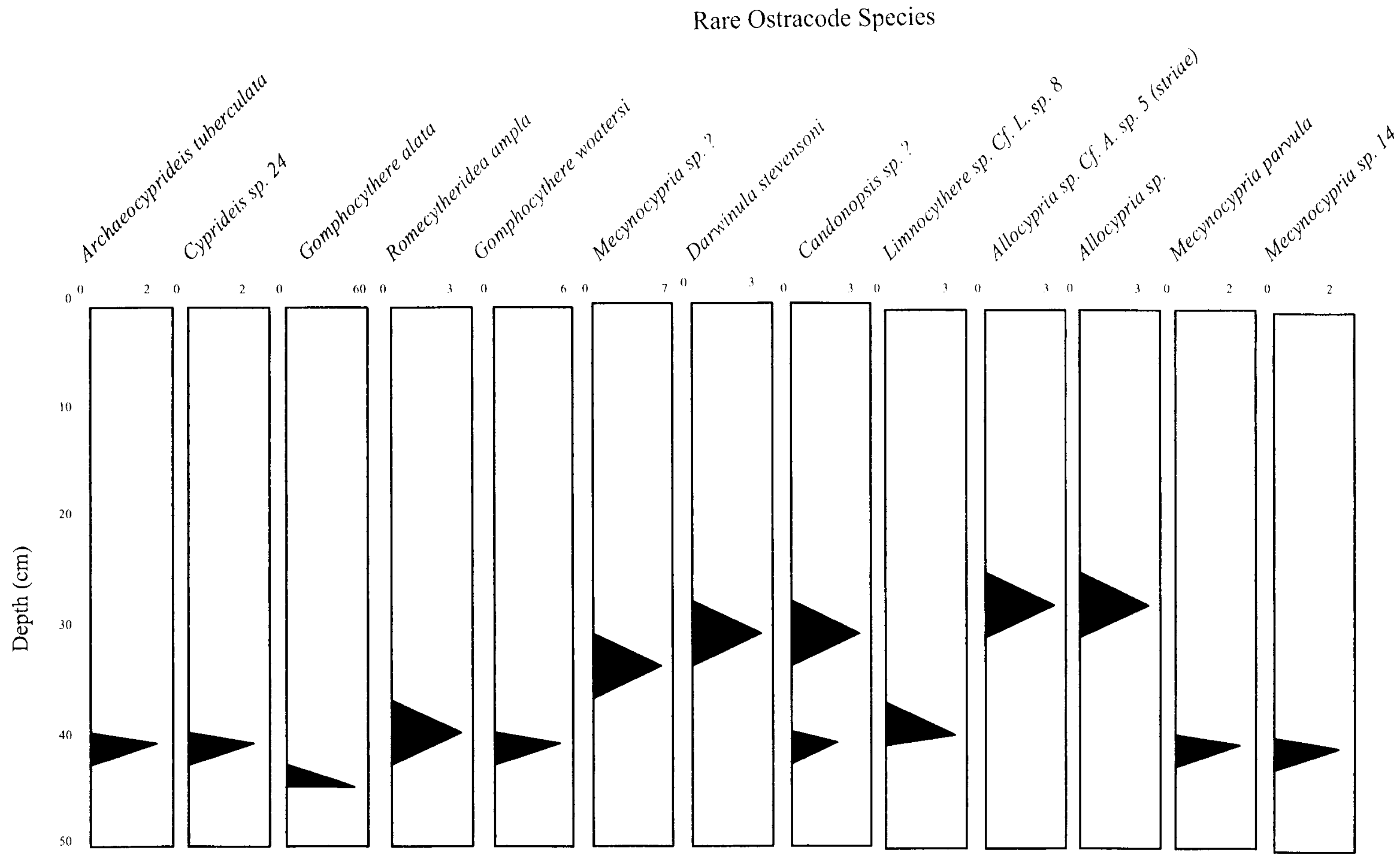
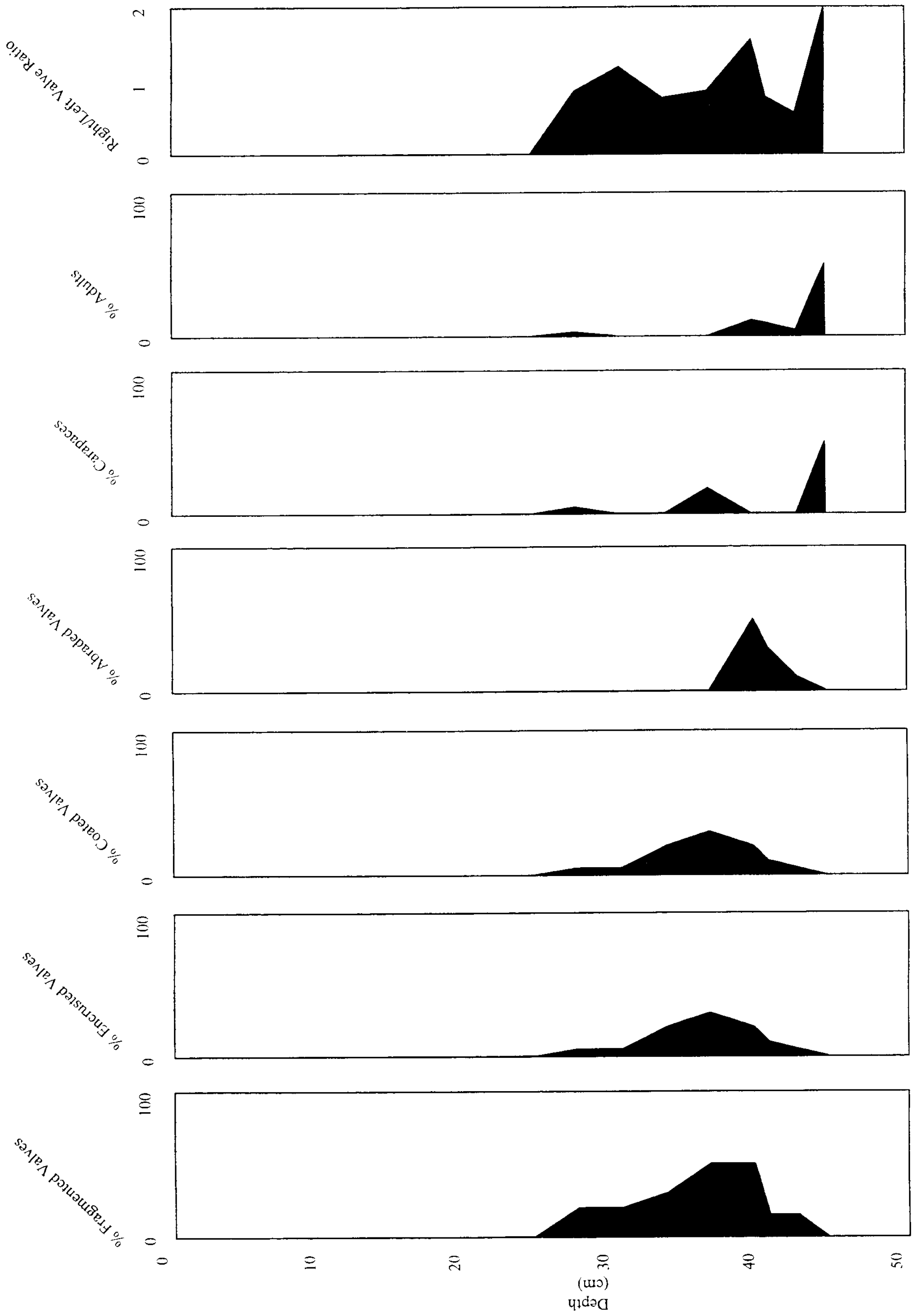


Fig. 3.26c



Core LT-98-82M

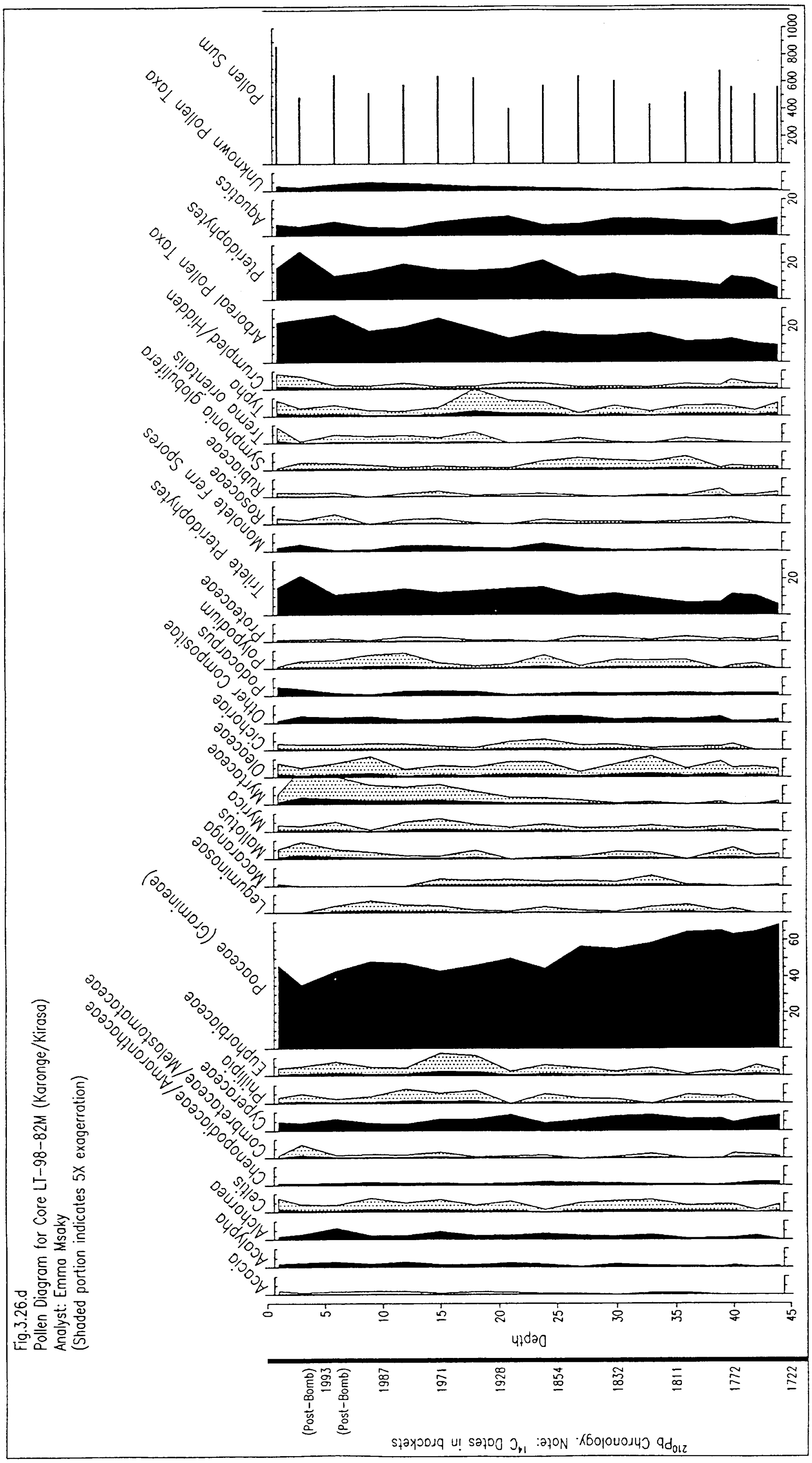


Fig.3.26.d
Pollen Diagram for Core LT-98-82M (Karonge/Kirasa)
Analyst: Emma Msaky
(Shaded portion indicates 5X exagerration)

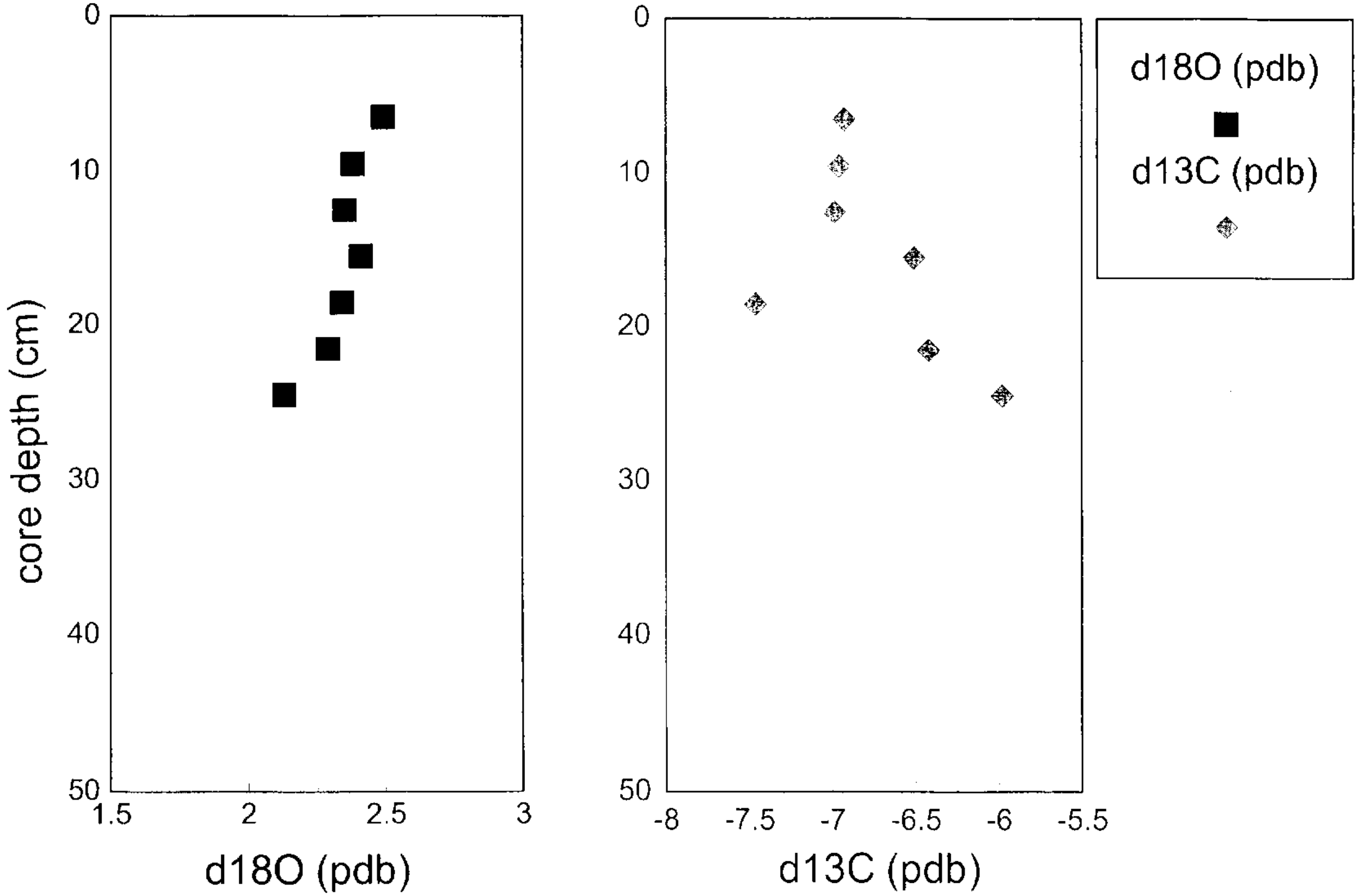


Fig. 3.27a. Stable Isotope Stratigraphy for *Romecytheridea* sp. 13 from Core 2M

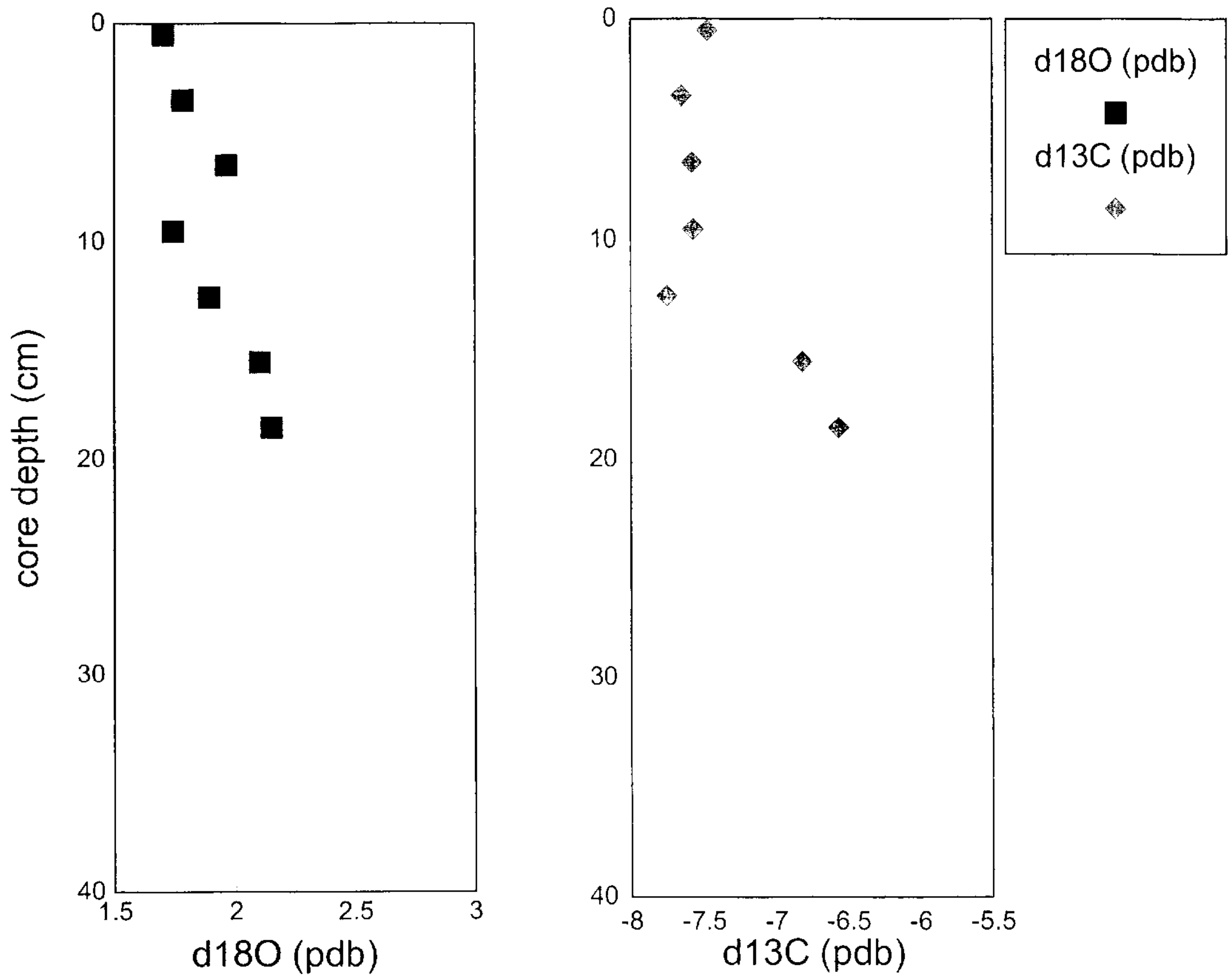


Fig. 3.27b. Stable Isotope Stratigraphy for *Romecytheridea* sp. 13 from Core 18

APPENDIX 1 - SAMPLING STATIONS

LUBULUNGU

Station #	Date/ Time	Lat. Dec. Deg. S.	Long. Dec Deg. E	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-1	7/1/98-0930	-6.16533	29.70533	100		G					Grn-blk. Gravelly sand	10cm-disturbed and bagged				
LT-98-2	7/1/98-1025	-6.16583	29.706	110	M			W			brn-massive mud	avg 49cm-good condition	copepods swimming in core barrel water-not anoxic		x (6.10.12S, 29.42.40 E) @106m	
		-6.16633	29.70733							?						Not in Dirk's list
LT-98-3	7/1/98-1340	-6.17517	29.69867	120		G					blk. Mud	86cm,disturbed at top				
LT-98-4	7/1/98-1520	-6.17617	29.698	120	M			W			shelly clay	46cm., good			x (collected w/sampler at 6.10.68S, 29.41.79E @115m)	same location as H2O sample
		-6.178	29.6965							P						
LT-98-5	7/1/98-1630	-6.16467	29.69783	115		G					blk grav. Sand	56cm				
LT-98-6	7/1/98-1715	-6.1465	29.70983	164		G					blk. Sand	40cm				
LT-98-7	7/1/98-1800	-6.151	29.708	151	M			W			blk. lam clay/ooze	53cm	excellent cond.		x	
LT-98-8	8/1/98-0900	-6.15567	29.72633	35				W		P			Lubulungu Delta		x(sampled offshore)	32 m vertical in 35 m water depth

LUBULUNGU CONTINUED

Station #	Date/ Time	Lat. Dec. Deg. S.	Long. Dec Deg. E	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-9	8/1/98-0850			river mouth				W	WR					0.2 um filter river water	x-100m upstream	from mouth
LT-98-10	8/1/98-1040	-6.1655	29.71783	87	M (failed-sandy)											
LT-98-11	8/1/98-1110	-6.163	29.71567	93	M			W			shelly sand	10cm	Tiphobia, Anceya, P. iridescens; poss. Corr. Prob. Between cores		x	
LT-98-12	8/1/98-1158	-6.15567	29.71267	126	M						blk. Silty sand	40cm	shelly			
LT-98-13	8/1/98-1630	-6.14133	29.70167	189	M			W			ooze+silt, part laminated	40.5cm	graded intervals		x	
LT-98-14	8/1/98-1631	-6.14233	29.7025							P						182 m vertical in 185 m water depth

KABESI

Station #	Date/ Time	Lat. Dec.Deg.S.	Long. Dec. Deg.E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-15	10/1/98 -0935	-5.975	29.79567	106	M						Flocculent,olive green to black clay - excellent		52 cm - good condition			
LT-98-16	10/1/98 -1025	-5.9835	29.78733	66.3	M											
LT-98-17	10/1/98 -1130	-5.99267	29.81	River mouth				W							Samples collected at 180° from Explorer on shore	
LT-98-18	10/1/98 -1305	-5.97683	29.81667	75	M						Brown mud - good	42 cm - good condition		Live Paramelania and copepods		
LT-98-19	10/1/98 -1415	-5.97217	29.81633	77		G						No length available - good condition	Near LT-98-18			
LT-98-20	10/1/98 -1430	-5.97117	29.82017	78						???P						Not in Dirk's list
LT-98-20	11/1/98 -0800	-5.9625	29.81333	105	M			W			Bacterial mat, grayish olive green clay - excellent		55 cm - excellent condition			

KABESI CONTINUED

Station #	Date/ Time	Lat. Dec.Deg. S.	Long. Dec. Deg.E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-21	11/1/98-0910	-5.969	29.775	141	M						Olive green to black clay and micaceous sand - good	40 cm - good condition	Only one core saved for radionuclides			
LT-98-22	11/1/98-1000	-5.98183	29.786	83	M						Alternate sand and dark mud layers - disturbed	35 cm - poor condition	Two cores discarded			
LT-98-23	11/1/98-1035	-5.986	29.77083	85	M						Brown clay and sandy clay - good	42 cm - slightly disturbed at top	Only one core saved for radionuclides			
LT-98-24	11/1/98-1245	-5.96	29.61117	393	M								Overpenetrated with 150 lbs			
LT-98-25	11/1/98-1320	-5.95933	29.61167	394	M				WR			52 cm - excellent condition	75 lbs weight; one core archived, two sliced		0.2 um filter river water	
LT-98-26	11/1/98-1430	-5.95967	29.61183	395		G		W		P		173 cm - good condition	Core top present but slightly disturbed; 120 lbs weight			Chris Scholz's site

NYASANGA/KAHAMA (GOMBE AREA)

Station #	Date/ Time	Lat. Dec. Deg S)	Long. Dec. Deg. E	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-50	14/1/98- 1250	-4.638333	29.628	87	M								Failed; rocky			
LT-98-51	14/1/98- 1210	-4.638	29.627667	54	M								Failed; triggered on sand			
LT-98-52	14/1/98- 1230	-4.637333	29.6275	67	M								Failed; didn't triggered			
LT-98-53	14/1/98- 1245	-4.638833	29.6275	96	M								Failed			
LT-98-54	15/1/98- 0900	-4.6745	29.618833	141	M								Failed; dark sandy mud on feet			
LT-98-55	15/1/98- 0915	-4.675833	29.618	97	M								Failed			
LT-98-56	15/1/98- 0935	-4.675	29.6195	65	M								Failed; lost two weights in bounce			
LT-98-57	15/1/98- 0955	-4.679167	29.616333	59	M								Failed; shell gravel			
LT-98-58	15/1/98- 1015	-4.688333	29.616667	76	M						Brown to dark clay- good	39 cm- excellent	Coordinates approximate; GPS not working properly			
LT-98-59	15/1/98- 1130	-4.6885	29.6145	63	M								Failed			
LT-98-60	15/1/98- 1140	-4.6885	29.618333	50	M								Failed			
LT-98-61	15/1/98- 1155	-4.688	29.618	91	M						Brown to dark clay- good	44 cm-good	One core only; split in two parts			
LT-98-62	15/1/98- 1200	-4.6875	29.615	135						P						40 m in 135 m water column
LT-98-63	15/1/98- 1230	-4.687167	29.618167	77		G					Brown to dark clay- good	148 cm-good	To be correlated with LT-98-58			

NYASANGA/KAHAMA (GOMBE AREA) CONTINUED

Station #	Date/ Time	Lat. Dec. Deg S)	Long. Dec. Deg. E	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-64A	15/1/98-1450	-4.6875			Nyasanga Stream			W								More southerly site
LT-98-64B	15/1/98-1450	-4.6895		Kahama Stream				W								More northerly site
LT-98-65	15/1/98-1530	-4.687667	29.616167	160	M								Failed; rock damaged core tube			
LT-98-66	15/1/98-1545	-4.685167	29.616667	129		G							Failed			
LT-98-67	15/1/98-1620	-4.699	29.616333	36						P						36 m in 36 m water column
LT-98-68	16/1/98-0830	-4.688333	29.62	26			D					6 cm- good	Penetrated 20 cm but disturbed; bagged sample			
LT-98-69	16/1/98-0830	-4.689167	29.618167	42									Eckman dredge; failed			
LT-9870	16/1/98-1030	-4.687167	29.614167	213		G							Failed; nose core bent. Rocky and sandy bottom			
LT-98-71	16/1/98-1055	-4.69	29.613167	100		G										

MWAMGONGO

Station #	Date/ Time	Latitude Dec.Deg.S.	Long.Dec Deg.E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-26	12/1/98-1540	-4.64283	29.626167	120		G		W?		P	Black sandy clay	NA	Core liner washed out on recovery		100 m from 398 m depth	100 m from 398 m depth
LT-98-27	12/1/98-1555	-4.63967	29.627167	89	M							NA	Water sample triggered but not corers			
LT-98-28	12/1/98-1615	-4.64	29.627	125	M							NA	No recovery, same problem as above; extremely steep slope (25°+)			
LT-98-29	12/1/98-1640	-4.64067	29.626667	120		G					Clayey sand, some cobbles	NA	Core lost, it drained out on recovery			
LT-9-30	12/1/98-1700	-4.63933	29.624333	225		G						NA	Very inaccurate			
LT-98-31	12/1/98-1735	-4.62317	29.632	107	M						Olive green to black clay-good	43 cm-excellent	Two successful cores, one failed			
LT-98-32	12/1/98-1815	-4.624	29.633333	66	M							NA	Washed out, small amount of sand in tubes			
LT-98-33	12/1/98-1825	-4.62317	29.633167	80	M								Failed to trip			
LT-98-34	12/1/98-1835	-4.62317	29.633167	77	M								+5m measured from winch; closed with muddy water but not sample			
LT-98-35	12/1/98-1845	-4.62267	29.633667	87	M						Reddish brown to black clay-good	41 cm-good	Only one core saved for radionuclides			
LT-98-36	13/1/981050	-4.62433	29.632167	104	M						Reddish brown to black clay-good	45 cm - excellent	Cores tilted 4 cm across 10 cm diameter core			
LT-98-37	13/1/98-1200	-4.62267	29.633167	95	M						Brown clay-good	45 cm - excellent	Snail			
LT-98-38	13/1/98-1305	-4.62233	29.636	75	M											

MWAMGONGO CONTINUED

Station #	Date/ Time	Latitude Dec.Deg.S.	Long.Dec Deg.E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18	Plankton Samples
LT-98-39	13/1/98-1650	-4.62317	29.635333	71	M						Reddish sandy clay to black gravelly sand	20 cm - excellent	Shell fragments at bottom of cores. 7 m deeper than echosounder			
LT-98-40	13/1/98-1500	Mwamgongo River mouth						W								1.5 km upstream; 150 m above lake level
LT-98-41	13/1/98-1725	-4.62083	29.616833	171	M								Failed. Insufficient penetration.			
LT-98-42	13/1/98-1745	-4.62067	29.634833	145	M								Failed			
LT-98-43	13/1/98-1758	-4.62083	29.6365	130	M								Failed			
LT-98-44	13/1/98-2015	-4.611	29.6335	40				W		P						Total water depth 252 m
LT-98-45	14/1/98-0750	-4.62433	29.634333	66		G							No recovery			
LT-98-46	14/1/98-0810	-4.62317	29.635	85		G							Nose cone jammed. Removed in Kigoma			
LT-98-47	14/1/98-0950	-4.6225	29.631167	208	M								Failed, too steep			
LT-98-48	14/1/98-1020	-4.622	29.633167	138	M								Failed, did not triggered			
LT-98-49	14/1/98-1035	-4.62217	29.632667	132	M						Fecal strings on top of core, no overpenetration	58 cm - good	Slight smearing on top			

KARONGE/KIRASA/NYAMUSENI/GATORONGORO

Station #	Date/ Time	Lat. Dec. Deg. S.	Long. Dec. Deg. E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18
LT-98-81	25/1/98-0730	-3.5835	29.325167	96	M								Failed-A little too successful		
LT-98-82	25/1/98-0756	-3.5835	29.325167	96	M			X		X	Flocculent black clay-Good	46cm-Excellent	Removed all weights		
LT-98-83	25/1/98-1015	-3.583333	29.342	29	M								Only water bottle triggered		
LT-98-84	25/1/98-1030	-3.584167	29.341833	36	M			X			Sand to sandy clay-Good	18cm-Good	Only one core recovered		
LT-98-85	25/1/98-1057	-3.582833	29.341833	27	M								Failed, it didn't trigger		
LT-98-86	25/1/98-1110	-3.584333	29.342	30	M								Failed, it got just a few cm's		
LT-98-87	25/1/98-1121	-3.583167	29.341667	32		G						20cm- Good	Short core		
LT-98-88	25/1/98-1140	-3.584	29.341667	30		G							Failed, tried rapid desent from 20m to bottom		
LT-98-89	25/1/98-1202	-3.583167	29.336	75	M			X			Flocculent brown clay-Good	33cm-Excellent	One disturbed, two good		
LT-98-90	25/1/98-1430	-3.591667	29.339667	70	M			X			Reddish brown clay-Good	37cm-Excellent	Two good cores, two disturbed		
LT-98-91	25/1/98-1609	-3.590167	29.332833	91	M			X			Laminated clay and silty clay-Good	34cm-Excellent	Two excellent cores, two disturbed		
LT-98-92	26/1/98-0700	-3.595667	29.343333	57	M			X			Brownish gray sandy silt-Fair	39cm-Slightly disturbed	Three cores recovered, some disturbance in all 3		
LT-98-93	26/1/98-0815	-3.595333	29.343167	93	M			X			Reddish brown silty clay-Good	24cm-Good	One good, two disturbed		

KARONGE/KIRASA/NYAMUSENI/GATORONGORO CONTINUED

Station #	Date/ Time	Lat. Dec. Deg. S.	Long. Dec. Deg. E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18
LT-98-94	26/1/98-0930	-3.595	29.343833	48		G					Sandy	30cm-Good	Short core		
LT-98-95	26/1/98-1010	-3.620667	29.340833	46	M							Core discarded	Failed, only very short core (<10cm). Very sandy.		
LT-98-96	26/1/98-1025	-3.617833	29.341	53	M			X			Brown silt to sand	15cm-Good	3 good cores, 1 disturbed		
LT-98-97	26/1/98-1100	-3.619	29.340333	43		G							Very short, sand stuck in between lier and core. Lost.		
LT-98-98A	26/1/98-1305	-3.619333	29.340167	60	M			X			Brown clayey sand-Good	37cm-Excellent	All triggered, but 3/4 very disturbed. Kept one good core.		
LT-98-98B	26/1/98-1328	-3.6195	29.34	61	M						Brown clayey sand-Good	40cm-Excellent	2/3 disturbed, kept one good core.		
LT-98-99	27/1/98-0655	-3.619167	29.335	99	M								Went into soft sediment but failed to trigger.		
LT-98-100	27/1/98-0720	-3.621333	29.334667	102	M			X			Pale brown to black clay-Good	38cm-Excellent	1 good core, 2 disturbed		
LT-98-101	27/1/98-0730	-3.623333	29.334333	108	M								Failed, went into sediment but didn't trigger.		
LT-98-102	27/1/98-0750	-3.621833	29.335667	100	M								Failed, went into sediment but didn't trigger.		
LT-98-103	27/1/98-0820	-3.6225	29.336167	97	M								Failed, triggered but liners didn't close properly.		
LT-98-104	27/1/98-0850	-3.626	29.335167	103	M			X			Brown to black laminated clay-Good	44cm-Excellent	2 good cores, 2 slightly disturbed.		

KARONGE/KIRASA/NYAMUSENI/GATORONGORO CONTINUED

Station #	Date/ Time	Lat. Dec. Deg. S.	Long. Dec. Deg. E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18
LT-98-105	27/1/98-0950	-3.635333	29.338667	87	M			X			Flocculent, brown to black silt, sand and clay-Good	33cm-Excellent	2 good cores, 2 slightly disturbed.		
LT-98-106	27/1/98-1040	-3.6355	29.339167	66		G							Washed out!		
LT-98-107	27/1/98-1145	-3.587333	29.337167	78	M			X			Flocculent, reddish brown to black silty clay-Good	43cm-Excellent	2 good cores, 1 disturbed.		

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Station #	Date/ Time	Latitude Dec. Deg. S.	Longitude Dec. Deg.E.	Water Depth (m)	Multi-core	Gravity Core	Diving Core	Water O-18	Water U/Th	Plankton	Core Lithology/ Quality	Core Length/ Condition	Comments on core	Water Samples U/Th	Water Samples O-18
LT-98-72m	20/1/98 0830	-4.958333	29.658333	64	x			2		x	reddish brn. Clay top to dk clay bottom	41			
LT-98-73m	20/1/98 0930	-4.973333	29.664833	72	0-failed to trigger										
LT-98-74m	20/1/98 0940	-4.973	29.664333	75	x			x			Red clay down to olive grn to dark clay	45			
LT-98-75m	20/1/98 1055	-4.949333	29.642	94	x			x			" laminated in part	48			
LT-98-76m	20/1/98 1250	-4.9795	29.6545	106	x			x		x	" "	49			
LT-98-77m	20/1/98 1440	-4.955	29.666667	55	x						" "	31/36			
LT-98-78m	21/1/98 1215	-4.996167	29.687333	77	x			x			" "	41			
LT-98-79m	21/1/98 1320	-4.994667	29.701833	60	x(discarded)						shelly dark sand				
LT-98-80m	21/1/98 1340	-4.9945	29.704833	57	x						reddish brn. Sandy mud down to shelly sand	15			
LT-98-81g	21/1/98 1435	-4.998167	29.686333	80		x					drk gray stiff mud/gas				

APPENDIX 2a Core 18m
Pb-210

PO-210/Pb-210
CALCULATION

Background Pb-210 1.91
Standard Deviation 0.07144361

Tracer Activity 10.1
(dpm)-

Core ID- LT18

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT18-0	0-1	0.5	3.2120	16	140197	1840	16216	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	0.78 ± 0.018	6.94 ± 0.000	27.92 ± 0.209	26.01 ± 0.22	39
LT18-1	1-2	1.5	3.1130	17	140158	2214	18585	0.00 ± 0.00E+00	0.0000 ± 0.00E+00	0.95 ± 0.020	7.96 ± 0.000	27.23 ± 0.178	25.32 ± 0.19	47
LT18-1RP	1-2	1.5	1.7268	18	107935	1857	9251	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.03 ± 0.024	5.14 ± 0.000	29.18 ± 0.116	27.27 ± 0.14	51
LT18-2	2-3	2.5	3.3803	18	140161	1492	13724	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	0.64 ± 0.017	5.87 ± 0.000	27.55 ± 0.239	25.64 ± 0.25	32
LT18-(9-10RP)	9-10	9.5	1.4975	7	102393	1683	3434	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	0.98 ± 0.024	2.01 ± 0.000	13.81 ± 0.050	11.90 ± 0.09	49
LT18-10	10-11	10.5	3.3099	7	107958	706	3398	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	0.39 ± 0.015	1.89 ± 0.000	14.84 ± 0.185	12.93 ± 0.20	19
LT18-10RP	10-11	10.5	3.2984	8	107980	562	2464	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.31 ± 0.013	1.37 ± 0.000	13.65 ± 0.191	11.74 ± 0.20	15
LT18-(10-11)	10-11	10.5	0.3515	16	133110	3639	1751	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.63 ± 0.027	0.79 ± 0.000	13.81 ± 0.008	11.90 ± 0.07	81
LT18-11	11-12	11.5	3.1875	9	107950	1054	3960	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	0.58 ± 0.018	2.20 ± 0.000	11.97 ± 0.117	10.06 ± 0.14	29
LT18-(11-12)	11-12	11.5	1.5487	18	133109	3185	6242	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.43 ± 0.025	2.81 ± 0.000	12.79 ± 0.035	10.88 ± 0.08	71
LT18-12	12-13	12.5	3.1335	10	107947	517	1937	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	0.28 ± 0.013	1.07 ± 0.000	12.19 ± 0.168	10.28 ± 0.18	14
LT18-(12-13)	12-13	12.5	1.5467	19	133108	3297	6039	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	1.48 ± 0.026	2.72 ± 0.000	11.98 ± 0.032	10.07 ± 0.08	73
LT18-13	13-14	13.5	3.0283	11	107946	975	2850	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	0.54 ± 0.017	1.58 ± 0.000	9.79 ± 0.095	7.88 ± 0.12	27
LT18-(13-14)	13-14	13.5	2.0799	20	133108	2520	5017	0.00 ± 4.64E-06	0.0013 ± 4.64E-06	1.13 ± 0.023	2.26 ± 0.000	9.67 ± 0.040	7.76 ± 0.08	56
LT18-14	14-15	14.5	3.1543	12	107945	810	1929	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.45 ± 0.016	1.07 ± 0.000	7.67 ± 0.085	5.76 ± 0.11	22
LT18-(14-15)	14-15	14.5	1.7909	1	102399	1430	2061	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.83 ± 0.022	1.21 ± 0.000	8.19 ± 0.039	6.28 ± 0.08	41
LT18-15	15-16	15.5	3.1842	13	107944	616	1590	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	0.33 ± 0.014	0.88 ± 0.000	8.38 ± 0.110	6.47 ± 0.13	16
LT18-(15-16)	15-16	15.5	1.7344	2	102421	1516	2064	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.89 ± 0.023	1.21 ± 0.000	7.94 ± 0.035	6.03 ± 0.08	44
LT18-16	16-17	16.5	3.0835	14	107943	630	1363	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	0.34 ± 0.014	0.75 ± 0.000	7.18 ± 0.089	5.27 ± 0.11	17
LT18-(16-17)	16-17	16.5	2.4896	4	102122	1093	1883	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.64 ± 0.019	1.11 ± 0.000	7.02 ± 0.053	5.11 ± 0.09	32
LT18-17	17-18	17.5	3.1938	15	107942	632	1046	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	0.34 ± 0.014	0.57 ± 0.000	5.33 ± 0.069	3.42 ± 0.10	17
LT18-(17-18)	17-18	17.5	1.4129	5	102393	1452	1120	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.84 ± 0.022	0.65 ± 0.000	5.57 ± 0.021	3.66 ± 0.07	42
LT18-18	18-19	18.5	3.0045	16	107941	645	697	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	0.35 ± 0.014	0.38 ± 0.000	3.66 ± 0.044	1.75 ± 0.08	17
LT18-(18-19)	18-19	18.5	2.2457	6	102392	343	304	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.20 ± 0.011	0.17 ± 0.000	3.96 ± 0.048	2.05 ± 0.09	10
LT18-19 #1	19-20	19.5	3.3751	17	107941	714	992	0.00 ± 0.00E+00	0.0000 ± 0.00E+00	0.40 ± 0.015	0.55 ± 0.000	4.16 ± 0.052	2.25 ± 0.09	20
LT18-19 #2	19-20	19.5	3.3751	11	203542	1020	1235	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	0.30 ± 0.009	0.36 ± 0.000	3.64 ± 0.038	1.73 ± 0.08	15
LT18-(19-20)	19-20	19.5	1.5413	13	80275	1529	756	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.13 ± 0.029	0.56 ± 0.000	3.24 ± 0.013	1.33 ± 0.07	56
LT18-(20-21)	20-21	20.5	1.5508	14	80273	1249	643	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	0.92 ± 0.026	0.46 ± 0.000	3.25 ± 0.014	1.34 ± 0.07	46
LT18-(21-22RP)	21-22	21.5	1.5717	5	178337	1910	997	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.63 ± 0.015	0.33 ± 0.000	3.39 ± 0.012	1.48 ± 0.07	31
LT18-(21-22)	21-22	21.5	1.5090	15	80308	1466	640	0.01 ± 1.33E-05	0.0078 ± 8.04E-06	1.08 ± 0.029	0.47 ± 0.000	2.90 ± 0.011	0.99 ± 0.07	54
LT18-(22-23)	22-23	22.5	1.5500	16	80324	1395	501	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.04 ± 0.028	0.37 ± 0.000	2.33 ± 0.010	0.42 ± 0.07	51
LT18-(23-24)	23-24	23.5	1.5223	18	80344	1699	642	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.27 ± 0.031	0.48 ± 0.000	2.50 ± 0.009	0.59 ± 0.07	63
LT18-(24-25)side 1	24-25	24.5	1.5630	19	80359	1494	689	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	1.11 ± 0.029	0.51 ± 0.000	2.98 ± 0.012	1.07 ± 0.07	55
LT18-(24-25)side 2	24-25	24.5	1.5630	18	177899	256	126	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	0.08 ± 0.005	0.04 ± 0.000	3.13 ± 0.031	1.22 ± 0.08	4
LT18-(25-26)	25-26	25.5	1.5387	20	80382	1786	826	0.00 ± 4.64E-06	0.0013 ± 4.64E-06	1.33 ± 0.032	0.62 ± 0.000	3.03 ± 0.011	1.12 ± 0.07	66

APPENDIX 2a CONTINUED

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT18-(26-27)	26-27	26.5	1.5261	1	178560	2258	1294	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.75 ± 0.016	0.43 ± 0.000	3.82 ± 0.012	1.91 ± 0.07	37
LT18-(27-28)	27-28	27.5	1.5730	2	178411	2578	1185	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.86 ± 0.017	0.40 ± 0.000	2.94 ± 0.009	1.03 ± 0.07	43
LT18-(28-29)	28-29	28.5	1.5513	4	178385	2108	1014	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.71 ± 0.015	0.34 ± 0.000	3.14 ± 0.011	1.23 ± 0.07	35
LT18-(29-30)	29-30	29.5	1.5760	1	142530	2066	893	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.86 ± 0.019	0.37 ± 0.000	2.78 ± 0.010	0.87 ± 0.07	43
LT18-(30-31)	30-31	30.5	1.5296	2	142572	2214	814	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.93 ± 0.020	0.34 ± 0.000	2.42 ± 0.008	0.51 ± 0.07	46
LT18-(31-32)	31-32	31.5	1.5289	4	141857	2190	817	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.92 ± 0.020	0.34 ± 0.000	2.47 ± 0.008	0.56 ± 0.07	46
LT18-(32-33)	32-33	32.5	1.5723	5	142620	2208	844	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.92 ± 0.020	0.35 ± 0.000	2.47 ± 0.008	0.56 ± 0.07	45
LT18-(33-34)	33-34	33.5	1.5909	6	142636	2238	796	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.94 ± 0.020	0.33 ± 0.000	2.24 ± 0.007	0.33 ± 0.07	46
LT18-(35-36)	35-36	35.5	1.5234	1	160970	2472	760	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.91 ± 0.019	0.28 ± 0.000	2.05 ± 0.006		45
LT18-(36-37)	36-37	36.5	1.4776	2	161064	2523	738	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.94 ± 0.019	0.27 ± 0.000	1.99 ± 0.006		46
LT18-(37-38)	37-38	37.5	1.5309	4	161104	2248	720	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.83 ± 0.018	0.27 ± 0.000	2.12 ± 0.007		41
LT18-(38-39)	38-39	38.5	1.5312	5	161147	2716	807	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	1.00 ± 0.019	0.30 ± 0.000	1.97 ± 0.006		50
LT18-(39-40)	39-40	39.5	1.5371	6	161190	2488	709	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.92 ± 0.019	0.26 ± 0.000	1.85 ± 0.006		46
LT18-(40-41)	40-41	40.5	1.4519	7	161236	2784	747	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.03 ± 0.020	0.28 ± 0.000	1.86 ± 0.005		51
LT18-(41-42)	41-42	41.5	1.5136	8	161299	2512	625	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.93 ± 0.019	0.23 ± 0.000	1.66 ± 0.005		46
LT18-(41-42)RP	41-42	41.5	1.4548	9	161334	3548	922	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.32 ± 0.022	0.34 ± 0.000	1.80 ± 0.004		65
LT18-3	3-4	3.5	3.0360	19	140164	1168	7904	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	0.50 ± 0.015	3.38 ± 0.000	22.63 ± 0.200	20.72 ± 0.21	25
LT18-4	4-5	4.5	3.1878	20	140149	1646	11699	0.00 ± 4.64E-06	0.0013 ± 4.64E-06	0.70 ± 0.017	5.01 ± 0.000	22.54 ± 0.176	20.63 ± 0.19	35
LT18-5	5-6	5.5	3.2885	2	107923	715	5216	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.39 ± 0.015	2.90 ± 0.000	22.55 ± 0.277	20.64 ± 0.29	20
LT18-6	6-7	6.5	3.3340	3	107962	837	4689	0.00 ± 0.00E+00	0.0000 ± 0.00E+00	0.47 ± 0.016	2.61 ± 0.000	16.97 ± 0.194	15.06 ± 0.21	23
LT18-7	7-8	7.5	3.0674	4	107958	746	4107	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.41 ± 0.015	2.28 ± 0.000	18.26 ± 0.205	16.35 ± 0.22	20
LT18-8	8-9	8.5	3.1321	5	107966	1210	5655	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.66 ± 0.019	3.14 ± 0.000	15.31 ± 0.139	13.40 ± 0.16	33
LT18-9	9-10	9.5	3.0579	6	107967	596	2552	0.00 ± 1.52E-05	0.0017 ± 1.28E-05	0.33 ± 0.014	1.42 ± 0.000	14.23 ± 0.178	12.32 ± 0.19	16
LT18-(9-10)	9-10	9.5	1.0870	15	133111	3307	4866	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.48 ± 0.026	2.19 ± 0.000	13.72 ± 0.026	11.81 ± 0.08	73

Appndix 2b. Core 58M Pb-210

PO-210/Pb-210 CALCULATION

Background Pb-210 3.00
Standard Deviation 3.3398E-05

Tracer Activity (dpm)- 10.1

Core ID- **LT58**

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT58-(0-1)	0-1	0.5	1.3815	1	76453	2048	5621	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.60 ± 0.036	4.41 ± 0.000	20.15 ± 0.061	17.15 ± 0.06	79
LT58-(1-2)	1-2	1.5	1.5112	2	76510	1849	5833	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	1.45 ± 0.034	4.57 ± 0.000	21.11 ± 0.074	18.11 ± 0.07	72
LT58-(2-3)RP	2-3	2.5	1.1406	4	76549	2042	4447	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	1.60 ± 0.035	3.48 ± 0.000	19.32 ± 0.048	16.32 ± 0.05	79
LT58-(3-4)	3-4	3.5	1.4981	5	76575	1856	4635	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	1.44 ± 0.034	3.63 ± 0.000	16.96 ± 0.059	13.96 ± 0.06	71
LT58-(4-5)	4-5	4.5	1.4554	6	76626	1872	3490	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	1.46 ± 0.034	2.73 ± 0.000	12.94 ± 0.043	9.94 ± 0.04	72
LT58-(5-6)	5-6	5.5	1.5006	7	76633	1701	2735	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.33 ± 0.032	2.14 ± 0.000	10.85 ± 0.039	7.85 ± 0.04	66
LT58-(6-7)	6-7	6.5	1.4625	8	76669	1986	2685	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	1.55 ± 0.035	2.10 ± 0.000	9.36 ± 0.031	6.36 ± 0.03	77
LT58-(8-9)	8-9	8.5	1.5237	9	76556	2472	2063	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.93 ± 0.039	1.62 ± 0.000	5.54 ± 0.017	2.54 ± 0.02	96
LT58-(9-10)	9-10	9.5	1.5437	10	76577	2567	1815	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	2.01 ± 0.040	1.42 ± 0.000	4.63 ± 0.014	1.63 ± 0.01	99
LT58-(10-11)	10-11	10.5	0.9575	11	76608	3240	1628	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	2.53 ± 0.045	1.27 ± 0.000	5.30 ± 0.009	2.30 ± 0.01	125
LT58-(11-12)	11-12	11.5	1.3644	12	76651	1505	1173	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.17 ± 0.030	0.92 ± 0.000	5.78 ± 0.020	2.78 ± 0.02	58
LT58-(12-13)	12-13	12.5	1.3789	13	76689	2104	1410	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.64 ± 0.036	1.10 ± 0.000	4.92 ± 0.015	1.92 ± 0.01	81
LT58-(13-14)	13-14	13.5	1.4316	14	76708	1817	1209	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.41 ± 0.033	0.93 ± 0.000	4.63 ± 0.015	1.63 ± 0.02	70
LT58-(14-15)	14-15	14.5	1.4160	15	76790	1953	1241	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.51 ± 0.035	0.96 ± 0.000	4.53 ± 0.014	1.53 ± 0.01	75
LT58-(15-16)	15-16	15.5	1.5505	16	76817	1478	890	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.15 ± 0.030	0.69 ± 0.000	3.92 ± 0.016	0.92 ± 0.02	57
LT58-(16-17)	16-17	16.5	1.5575	18	76817	1428	779	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.11 ± 0.030	0.61 ± 0.000	3.53 ± 0.014	0.53 ± 0.01	55
LT58-(2-3)	2-3	2.5	1.0676	19	76858	2680	5370	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	2.09 ± 0.040	4.19 ± 0.000	18.98 ± 0.039	15.98 ± 0.04	103
LT58-(17-18)	17-18	17.5	1.3815	1	105965	1563	787	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.88 ± 0.022	0.44 ± 0.000	3.70 ± 0.013	0.70 ± 0.01	43
LT58-(18-19)	18-19	18.5	1.5112	2	108310	1609	882	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.89 ± 0.022	0.49 ± 0.000	3.66 ± 0.014	0.66 ± 0.01	44
LT58-(20-21)	20-21	20.5	1.4981	5	108370	1698	740	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.93 ± 0.023	0.41 ± 0.000	2.96 ± 0.011		46
LT58-(20-21)RP	20-21	20.5	1.4554	6	108392	1649	727	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.91 ± 0.022	0.40 ± 0.000	3.04 ± 0.011		45

Appendix 2c. Core 37M Pb 210

PO-210/Pb-210 CALCULATION

Background Pb-210 2.56
Standard Deviation 0.00068172

Tracer Activity (dpm)- 10.1

Core ID- LT37

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT37(1-2)	1-2	1.5	0.4272	1	75848	1424	2289	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.12 ± 0.030	1.81 ± 0.000	38.23 ± 0.043	35.67 ± 0.04	55
LT37(2-3)	2-3	2.5	1.6466	2	75996	767	4535	0.00 ± 2.57E-03	0.0000 ± 1.51E-05	0.60 ± 0.022	3.58 ± 0.000	36.44 ± 0.217	33.89 ± 0.22	30
LT37(3-4)	3-4	3.5	1.4768	4	74641	851	3974	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.68 ± 0.023	3.19 ± 0.000	32.08 ± 0.162	29.53 ± 0.16	34
LT37(4-5)	4-5	4.5	1.5848	5	75915	822	3615	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.64 ± 0.023	2.86 ± 0.000	28.49 ± 0.159	25.94 ± 0.16	32
LT37(5-6)	5-6	5.5	1.6358	6	75999	814	3379	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.64 ± 0.023	2.66 ± 0.000	25.69 ± 0.146	23.14 ± 0.15	32
LT37(6-7)	6-7	6.5	1.4929	7	76010	938	3076	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	0.74 ± 0.024	2.43 ± 0.000	22.30 ± 0.108	19.75 ± 0.11	36
LT37(7-8)	7-8	7.5	1.5839	8	76014	921	2822	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.72 ± 0.024	2.23 ± 0.000	19.67 ± 0.102	17.12 ± 0.10	36
LT37(8-9)	8-9	8.5	1.0349	9	76142	1774	2946	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.39 ± 0.033	2.32 ± 0.000	16.24 ± 0.040	13.68 ± 0.04	69
LT37(8-9 RP)	8-9	8.5	0.9709	10	76167	1793	2708	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.41 ± 0.033	2.13 ± 0.000	15.73 ± 0.036	13.18 ± 0.04	70
LT37(10-11)	10-11	10.5	1.4597	11	76190	1746	2850	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.37 ± 0.033	2.24 ± 0.000	11.31 ± 0.039	8.75 ± 0.04	68
LT37(11-12)	11-12	11.5	1.6403	12	76216	1399	1884	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.10 ± 0.029	1.48 ± 0.000	8.31 ± 0.036	5.76 ± 0.04	54
LT37(13-14)	13-14	13.5	1.5979	6	92995	1380	1349	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.89 ± 0.024	0.87 ± 0.000	6.17 ± 0.026	3.62 ± 0.03	44
LT37(14-15)	14-15	14.5	1.5368	7	92995	1587	1434	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.02 ± 0.026	0.92 ± 0.000	5.95 ± 0.023	3.40 ± 0.02	50
LT37(15-16)	15-16	15.5	1.4508	8	92990	1504	1098	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.97 ± 0.025	0.71 ± 0.000	5.10 ± 0.019	2.55 ± 0.02	48
LT37(16-17)	16-17	16.5	1.5088	9	75925	1847	1155	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.46 ± 0.034	0.91 ± 0.000	4.19 ± 0.015	1.64 ± 0.01	72
LT37(17-18)	17-18	17.5	1.5022	10	75532	1800	1184	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.43 ± 0.034	0.94 ± 0.000	4.42 ± 0.016	1.87 ± 0.02	71
LT37(18-19)	18-19	18.5	1.5164	11	92489	1589	1093	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.03 ± 0.026	0.71 ± 0.000	4.58 ± 0.017	2.03 ± 0.02	51
LT37(19-20)	19-20	19.5	1.6404	12	92453	1337	865	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.86 ± 0.024	0.56 ± 0.000	3.99 ± 0.018	1.43 ± 0.02	43
LT37(21-22)	21-22	21.5	1.6605	13	75453	1557	913	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.23 ± 0.031	0.72 ± 0.000	3.57 ± 0.015	1.02 ± 0.02	61
LT37(21-22)RP	21-22	21.5	1.5046	14	75421	1545	840	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.22 ± 0.031	0.65 ± 0.000	3.57 ± 0.014	1.01 ± 0.01	60
LT37(22-23)	22-23	22.5	1.6342	15	75402	1511	809	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.19 ± 0.031	0.64 ± 0.000	3.30 ± 0.014	0.74 ± 0.01	59
LT37(23-24)	23-24	23.5	1.7288	16	92271	1582	778	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.02 ± 0.026	0.50 ± 0.000	2.87 ± 0.012	0.31 ± 0.01	51
LT37(32-33)	32-33	32.5	1.5805	11	133052	2841	1136	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.28 ± 0.024	0.51 ± 0.000	2.55 ± 0.008		63
LT37(33-34)	33-34	33.5	1.5595	4	133098	2536	1001	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	1.14 ± 0.023	0.45 ± 0.000	2.56 ± 0.008		56
LT37(34-35)	34-35	34.5	1.5089	5	133099	1756	695	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.78 ± 0.019	0.31 ± 0.000	2.67 ± 0.010		39
LT37(35-36)	35-36	35.5	1.5161	6	133101	2023	787	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.91 ± 0.020	0.35 ± 0.000	2.57 ± 0.009		45
LT37(36-37)	36-37	36.5	1.6713	7	133102	1990	770	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	0.89 ± 0.020	0.35 ± 0.000	2.34 ± 0.009		44
LT37(37-38)	37-38	37.5	1.5531	8	133102	2129	806	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.95 ± 0.021	0.36 ± 0.000	2.47 ± 0.008		47
LT37(37-38)RP	37-38	37.5	1.5567	9	133054	2825	1156	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.27 ± 0.024	0.52 ± 0.000	2.66 ± 0.008		63
LT37(38-39)	38-39	38.5	1.6517	10	133054	2563	1102	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.15 ± 0.023	0.49 ± 0.000	2.62 ± 0.009		57
LT37(39-40)	39-40	39.5	1.5306	8	142673	2352	1136	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.98 ± 0.020	0.48 ± 0.000	3.20 ± 0.010		49
LT37(40-41)	40-41	40.5	1.5648	13	142700	2858	1348	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.19 ± 0.022	0.56 ± 0.000	3.05 ± 0.009		59
LT37(41-42)	41-42	40.5	1.5169	14	142722	2765	1302	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.15 ± 0.022	0.53 ± 0.000	3.04 ± 0.009		57
LT37(42-43)	42-43	42.5	1.5310	15	143033	3170	1783	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.32 ± 0.024	0.74 ± 0.000	3.70 ± 0.010		65

Appendix 2d. Core 98 Pb-210
PO-210/Pb-210 CALCULATION

Background Pb-210 1.50
Standard Deviation 0.0002129

Tracer Activity (dpm)- 10.1

Core ID- **LT98A**

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT98-1	0-1	0.5	1.8972	1	145347	1248	1867	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.51 ± 0.015	0.77 ± 0.000	8.07 ± 0.044	6.57 ± 0.04	25
LT98-2	1-2	1.5	2.7667	2	145343	1035	2276	0.00 ± 1.60E-05	0.0026 ± 2.89E-03	0.42 ± 0.013	0.94 ± 0.003	8.06 ± 0.069	6.56 ± 0.07	21
LT98-3	2-3	2.5	2.2078	3	145342	1186	2204	0.00 ± 0.00E+00	0.0000 ± 0.00E+00	0.49 ± 0.014	0.91 ± 0.000	8.50 ± 0.054	7.00 ± 0.05	24
LT98-4	3-4	3.5	2.0220	4	145340	1461	2845	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.60 ± 0.016	1.17 ± 0.000	9.77 ± 0.051	8.27 ± 0.05	30
LT98-5	4-5	4.5	2.0119	5	145338	1500	2924	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.61 ± 0.016	1.21 ± 0.000	9.95 ± 0.052	8.45 ± 0.05	30
LT98-6	5-6	5.5	2.3431	6	145335	1481	3118	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.61 ± 0.016	1.28 ± 0.000	9.09 ± 0.055	7.59 ± 0.05	30
LT98-7	6-7	6.5	2.0750	8	145336	1285	2740	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.53 ± 0.015	1.13 ± 0.000	10.48 ± 0.061	8.98 ± 0.06	26
LT98-8	7-8	7.5	2.6632	13	145334	1907	4386	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	0.78 ± 0.018	1.81 ± 0.000	8.80 ± 0.054	7.30 ± 0.05	39
LT98-8RP	7-8	7.5	2.2325	14	145332	1727	3363	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	0.70 ± 0.017	1.37 ± 0.000	8.80 ± 0.048	7.30 ± 0.05	35
LT98-9	8-9	8.5	3.1175	15	145329	1767	2988	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	0.72 ± 0.017	1.23 ± 0.000	5.53 ± 0.041	4.03 ± 0.04	36
LT98-10	9-10	9.5	2.0815	16	145326	2330	2674	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	0.96 ± 0.020	1.10 ± 0.000	5.59 ± 0.024	4.09 ± 0.02	47
LT98-10-11	10-11	10.5	1.4983	9	93472	1859	1770	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.19 ± 0.028	1.13 ± 0.000	6.43 ± 0.022	4.93 ± 0.02	59
LT98-11-12	11-12	11.5	1.5261	10	93470	1818	1948	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.16 ± 0.027	1.25 ± 0.000	7.10 ± 0.025	5.60 ± 0.03	58
LT98-12-13	12-13	12.5	1.6170	11	93472	2173	2200	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.39 ± 0.030	1.41 ± 0.000	6.33 ± 0.022	4.83 ± 0.02	69
LT98-13-14	13-14	13.5	1.6808	12	93466	1499	1546	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.96 ± 0.025	0.99 ± 0.000	6.21 ± 0.027	4.71 ± 0.03	47
LT98-14-15	14-15	14.5	1.4314	13	93464	1980	1867	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.26 ± 0.029	1.19 ± 0.000	6.68 ± 0.021	5.18 ± 0.02	63
LT98-15-16	15-16	15.5	1.8029	14	133111	1942	2329	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	0.87 ± 0.020	1.03 ± 0.000	6.66 ± 0.027	5.16 ± 0.03	43
LT98-15-16s2	15-16	15.5	1.8029	14	93480	318	414	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	0.19 ± 0.011	0.25 ± 0.000	7.08 ± 0.075	5.58 ± 0.07	10
LT98-16-17	16-17	16.5	1.4938	15	93479	2073	2141	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.32 ± 0.029	1.37 ± 0.000	7.00 ± 0.023	5.50 ± 0.02	65
LT98-17-18	17-18	17.5	1.6946	16	93481	1915	1969	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.22 ± 0.028	1.26 ± 0.000	6.14 ± 0.024	4.64 ± 0.02	61
LT98-18-19	18-19	18.5	1.5595	18	93432	2053	2210	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.32 ± 0.029	1.42 ± 0.000	6.96 ± 0.024	5.46 ± 0.02	65
LT98-17-18rp	17-18	17.5	1.7170	13	133109	321	72	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	0.14 ± 0.008	0.03 ± 0.000	1.25 ± 0.013	-0.25 ± 0.01	7
LT98-20-21	20-21	20.5	1.5871	1	70319	1343	753	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.14 ± 0.031	0.64 ± 0.000	3.58 ± 0.015	2.08 ± 0.02	56
LT98-21-22	21-22	21.5	1.5343	2	70336	1273	1082	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	1.08 ± 0.030	0.92 ± 0.000	5.59 ± 0.024	4.09 ± 0.02	54
LT98-22-23	22-23	22.5	1.5289	4	70345	1214	1651	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	1.03 ± 0.030	1.41 ± 0.000	9.01 ± 0.039	7.51 ± 0.04	51
LT98-23-24	23-24	23.5	1.5442	5	70334	1231	1447	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	1.04 ± 0.030	1.23 ± 0.000	7.76 ± 0.034	6.26 ± 0.03	51
LT98-24-25	24-25	24.5	1.5373	6	70353	1230	1538	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	1.05 ± 0.030	1.31 ± 0.000	8.21 ± 0.036	6.71 ± 0.04	52
LT98-25-26	25-26	25.5	1.5277	7	70368	1210	1423	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.03 ± 0.030	1.21 ± 0.000	7.80 ± 0.034	6.30 ± 0.03	51
LT98-26-27	26-27	26.5	1.5794	8	70385	1211	1489	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	1.03 ± 0.030	1.27 ± 0.000	7.90 ± 0.036	6.40 ± 0.04	51
LT98-27-28	27-28	27.5	1.5447	13	70401	1608	2349	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.36 ± 0.034	2.00 ± 0.000	9.59 ± 0.037	8.09 ± 0.04	67
LT98-28-29	28-29	28.5	1.5037	14	70429	1548	2381	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.31 ± 0.034	2.01 ± 0.000	10.31 ± 0.039	8.81 ± 0.04	65
LT98-29-30	29-30	29.5	1.5533	15	70443	1570	2425	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.33 ± 0.034	2.06 ± 0.000	10.09 ± 0.039	8.59 ± 0.04	66
LT98-29-30RP	29-30	29.5	1.5366	16	70457	1399	2323	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.18 ± 0.032	1.97 ± 0.000	10.95 ± 0.045	9.45 ± 0.04	59
LT98-30-31	30-31	30.5	1.4835	10	161371	2465	819	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	0.91 ± 0.018	0.30 ± 0.000	2.25 ± 0.007	0.75 ± 0.01	45
LT98-31-32	31-32	31.5	1.6517	11	161421	3149	1169	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.17 ± 0.021	0.43 ± 0.000	2.26 ± 0.007	0.76 ± 0.01	58
LT98-32-33	32-33	32.5	1.6277	12	161446	2757	1018	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.02 ± 0.020	0.38 ± 0.000	2.29 ± 0.007	0.79 ± 0.01	51
LT98-33-34	33-34	33.5	1.4397	13	161490	2432	730	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	0.90 ± 0.018	0.27 ± 0.000	2.10 ± 0.006	0.60 ± 0.01	44
LT98-34-35	34-35	34.5	1.8560	14	161489	2884	1001	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.06 ± 0.020	0.35 ± 0.000	1.80 ± 0.006	0.30 ± 0.01	53
LT98-35-36	35-36	35.5	1.6182	15	161558	2723	924	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.00 ± 0.019	0.34 ± 0.000	2.09 ± 0.006	0.59 ± 0.01	50
LT98-36-37	36-37	36.5	1.5823	16	161593	2301	728	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	0.85 ± 0.018	0.27 ± 0.000	2.00 ± 0.007	0.50 ± 0.01	42
LT98-37-38	37-38	37.5	1.4887	18	161642	2866	942	0.00 ± 5.12E-06	0.0015 ± 4.84E-06	1.06 ± 0.020	0.35 ± 0.000	2.22 ± 0.006	0.72 ± 0.01	53
LT98-38-39	38-39	38.5	1.5081	19	161666	2612	860	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	0.97 ± 0.019	0.32 ± 0.000	2.20 ± 0.006	0.70 ± 0.01	48
LT98-39-40	39-40	39.5	1.6321	20	161689	2692	851	0.00 ± 4.64E-06	0.0013 ± 4.64E-06	1.00 ± 0.019	0.31 ± 0.000	1.95 ± 0.006	0.45 ± 0.01	49

Appendix 2e. Core 82 Pb-210
PO-210/Pb-210 CALCULATION

Background Pb-210 5.00
Standard Deviation 0.00260181

Tracer Activity (dpm)- 10.1

Core ID- LT82

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT82-1	0-1	0.5	0.8491	4	180636	2716	6486	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.90 ± 0.017	2.15 ± 0.027	28.50 ± 0.055	23.50 ± 0.05	45
LT82-3	2-3	2.5	3.1923	5	253183	655	7785	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.14 ± 0.006	1.84 ± 0.021	40.43 ± 0.557	35.43 ± 0.56	47
LT82-4	3-4	3.5	2.4645	6	253575	513	4296	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.12 ± 0.005	1.01 ± 0.016	34.90 ± 0.405	29.90 ± 0.41	46
LT82 (1-2)	1-2	1.5	1.3836	1	80066	1462	7784	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.09 ± 0.029	5.83 ± 0.066	39.12 ± 0.154	34.12 ± 0.15	54
LT82 (2-3)	2-3	2.5	1.5373	2	80106	1188	6799	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.89 ± 0.026	5.09 ± 0.062	37.70 ± 0.181	32.70 ± 0.18	44
LT82 (4-5)	4-5	4.5	1.5592	4	80140	1392	7232	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	1.04 ± 0.028	5.41 ± 0.064	33.75 ± 0.153	28.75 ± 0.15	51
LT82 (5-6)	5-6	5.5	0.7323	5	80139	1741	4429	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	1.29 ± 0.031	3.31 ± 0.050	35.36 ± 0.073	30.36 ± 0.07	64
LT82 (7-8)	7-8	7.5	1.5184	6	80156	1479	7665	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	1.10 ± 0.029	5.73 ± 0.066	34.53 ± 0.148	29.53 ± 0.15	55
LT82 (8-9)	8-9	8.5	1.5311	7	80178	1385	6225	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.03 ± 0.028	4.66 ± 0.059	29.77 ± 0.135	24.77 ± 0.13	51
LT82 (8-9RP)	8-9	8.5	1.6354	8	80188	1100	5803	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.82 ± 0.025	4.34 ± 0.057	32.79 ± 0.176	27.79 ± 0.18	40
LT82 (9-10)	9-10	9.5	0.6482	9	80202	2512	4199	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.88 ± 0.037	3.14 ± 0.048	26.08 ± 0.042	21.08 ± 0.04	93
LT82 (10-11)	10-11	10.5	1.5113	10	80207	1806	7445	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.35 ± 0.032	5.57 ± 0.065	27.61 ± 0.109	22.61 ± 0.11	67
LT82 (11-12)	11-12	11.5	1.5288	11	80233	1788	9553	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.33 ± 0.032	7.14 ± 0.073	35.37 ± 0.138	30.37 ± 0.14	66
LT82 (12-13)	12-13	12.5	1.5370	12	80258	1504	7400	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.12 ± 0.029	5.53 ± 0.064	32.42 ± 0.140	27.42 ± 0.14	55
LT82 (13-14)	13-14	13.5	1.4515	6	178308	3260	14640	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	1.09 ± 0.019	4.92 ± 0.041	31.30 ± 0.087	26.30 ± 0.09	54
LT82 (14-15)	14-15	14.5	1.5164	7	178283	2867	11996	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	0.96 ± 0.018	4.04 ± 0.037	27.99 ± 0.088	22.99 ± 0.09	48
LT82 (15-16)	15-16	15.5	0.6715	8	178250	3711	6243	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	1.24 ± 0.021	2.10 ± 0.027	25.40 ± 0.035	20.40 ± 0.04	62
LT82 (17-18)	17-18	17.5	1.4801	9	178214	2966	14959	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.00 ± 0.018	5.04 ± 0.041	34.53 ± 0.102	29.53 ± 0.10	49
LT82 (19-20)	19-20	19.5	1.5227	10	178176	2934	9273	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	0.98 ± 0.018	3.12 ± 0.032	21.02 ± 0.067	16.02 ± 0.07	49
LT82 (20-21)	20-21	20.5	1.4827	11	178146	3056	9491	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.03 ± 0.019	3.19 ± 0.033	21.21 ± 0.065	16.21 ± 0.06	51
LT82 (21-22)	21-22	21.5	1.4488	12	178107	3003	5548	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.01 ± 0.018	1.87 ± 0.025	12.91 ± 0.042	7.91 ± 0.04	50
LT82 (22-23)	22-23	22.5	1.5213	13	178058	4021	5239	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.35 ± 0.021	1.76 ± 0.024	8.69 ± 0.028	3.69 ± 0.03	67
LT82 (22-23)RP	22-23	22.5	1.5782	14	178031	3312	4594	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.11 ± 0.019	1.53 ± 0.023	8.84 ± 0.032	3.84 ± 0.03	55
LT82 (23-24)	23-24	23.5	1.4630	15	177992	1827	5229	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	0.60 ± 0.014	1.75 ± 0.024	20.03 ± 0.080	15.03 ± 0.08	30
LT82 (24-25)	24-25	24.5	1.5050	16	177953	3434	7690	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.15 ± 0.020	2.59 ± 0.030	15.09 ± 0.046	10.09 ± 0.05	57
LT82 (25-26)	25-26	25.5	1.3702	1	76744	1295	3966	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.01 ± 0.028	3.10 ± 0.049	22.73 ± 0.099	17.73 ± 0.10	50
LT82 (25-26)RP	25-26	25.5	1.3409	2	76745	1271	3896	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.99 ± 0.028	3.04 ± 0.049	23.14 ± 0.099	18.14 ± 0.10	49
LT82 (26-27)	26-27	26.5	1.5104	4	76742	1114	3924	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.87 ± 0.026	3.07 ± 0.049	23.64 ± 0.120	18.64 ± 0.12	43
LT82 (27-28)	27-28	27.5	1.4509	5	76743	1188	3150	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.92 ± 0.027	2.46 ± 0.044	18.66 ± 0.092	13.66 ± 0.09	45
LT82 (28-29)	28-29	28.5	1.4430	6	76744	1263	3076	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.99 ± 0.028	2.40 ± 0.043	17.06 ± 0.082	12.06 ± 0.08	49
LT82 (29-30)	29-30	29.5	1.4444	7	76745	1319	2767	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.03 ± 0.028	2.16 ± 0.041	14.72 ± 0.071	9.72 ± 0.07	51
LT82 (30-31)	30-31	30.5	1.4289	8	76746	1123	2308	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.87 ± 0.026	1.80 ± 0.038	14.61 ± 0.076	9.61 ± 0.08	43
LT82 (31-32)	31-32	31.5	1.4183	13	76730	1655	3528	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.29 ± 0.032	2.76 ± 0.046	15.26 ± 0.064	10.26 ± 0.06	64
LT82 (32-33)	32-33	32.5	1.4046	14	76732	1666	3002	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.29 ± 0.032	2.33 ± 0.043	12.94 ± 0.055	7.94 ± 0.06	64
LT82 (33-34)	33-34	33.5	1.4383	15	76733	1664	2656	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.29 ± 0.032	2.07 ± 0.040	11.26 ± 0.050	6.26 ± 0.05	64
LT82 (34-35)	34-35	34.5	1.4332	16	76732	1513	2398	0.01 ± 1.02E-05	0.0040 ± 8.04E-06	1.18 ± 0.030	1.87 ± 0.038	11.21 ± 0.052	6.21 ± 0.05	58
LT82 (35-36)	35-36	35.5	1.4579	1	156874	2389	3349	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	0.91 ± 0.019	1.28 ± 0.022	9.78 ± 0.038	4.78 ± 0.04	45
LT82 (36-37)	36-37	36.5	1.4800	2	156870	1823	2347	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	0.69 ± 0.016	0.90 ± 0.019	8.80 ± 0.040	3.80 ± 0.04	34
LT82 (37-38)	37-38	37.5	1.4312	4	156871	1962	2526	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	0.75 ± 0.017	0.97 ± 0.019	9.12 ± 0.039	4.12 ± 0.04	37
LT82 (38-39)	38-39	38.5	1.5118	5	156872	2122	2782	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.80 ± 0.018	1.06 ± 0.020	8.86 ± 0.039	3.86 ± 0.04	40
LT82 (39-40)	39-40	39.5	1.4937	6	156872	1685	2204	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	0.64 ± 0.016	0.84 ± 0.018	8.84 ± 0.042	3.84 ± 0.04	32
LT82 (40-41)	40-41	40.5	0.9975	7	156872	2925	2366	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.11 ± 0.021	0.90 ± 0.019	8.21 ± 0.022	3.21 ± 0.02	55
LT82 (41-42)	41-42	41.5	1.5945	8	156872	1802	2051	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.68 ± 0.016	0.78 ± 0.017	7.26 ± 0.037	2.26 ± 0.04	34
LT82 (41-42)RP	41-42	41.5	1.5007	9	156812	2422	2651	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	0.92 ± 0.019	1.01 ± 0.020	7.39 ± 0.031	2.39 ± 0.03	46
LT82 (42-43)	42-43	42.5	1.4686	10	156811	2373	2368	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	0.90 ± 0.019	0.90 ± 0.019	6.87 ± 0.029	1.87 ± 0.03	45
LT82 (43-44)	43-44	43.5	1.4855	11	156810	2486	2255	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	0.95 ± 0.019	0.86 ± 0.018	6.17 ± 0.026	1.17 ± 0.03	47
LT82 (44-45)	44-45	44.5	1.5174	12	156766	1645	1432	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.63 ± 0.016	0.55 ± 0.014	5.81 ± 0.032	0.81 ± 0.03	31

Appendix 2f. Core LT-97-14v Pb 210
PO-210/Pb-210 CALCULATION

Background Pb-210 1.71
Standard Deviation 0.00287501

Tracer Activity (dpm)- 10.1

Core ID- LT14

	Depth Interval cm	Depth Midpoint cm	Sample Mass g	Detector ID	Livetime sec.	Po-209 gross counts	Po-210 gross counts	Po-209 Background cpm	Po-210 Background cpm	Po-209 Net cpm	Po-210 Net cpm	Po-210 dpm/g	Excess Pb-210 dpm/g	Chemical Yield
LT14-(0-1)	0-1	0.5	0.7100	1	255647	5395	5681	0.01 ± 2.57E-05	0.0013 ± 1.07E-05	1.26 ± 0.017	1.33 ± 0.000	15.05 ± 0.014	13.34 ± 0.01	62
LT14-(1-2)	1-2	1.5	1.0600	2	255782	5348	4741	0.00 ± 1.60E-05	0.0026 ± 1.51E-05	1.25 ± 0.017	1.11 ± 0.000	8.45 ± 0.012	6.74 ± 0.01	62
LT14-(2-3)	2-3	2.5	1.2200	3	255754	5580	5309	0.00 ± 0.00E+00	0.0000 ± 0.00E+00	1.31 ± 0.018	1.25 ± 0.000	7.88 ± 0.013	6.17 ± 0.01	65
LT14-(3-4)	3-4	3.5	1.5100	4	255351	5417	5829	0.00 ± 1.69E-05	0.0006 ± 7.56E-06	1.27 ± 0.017	1.37 ± 0.000	7.21 ± 0.015	5.50 ± 0.01	63
LT14-(4-5)	4-5	4.5	2.1100	5	255830	4205	6072	0.01 ± 3.25E-05	0.0021 ± 1.41E-05	0.98 ± 0.015	1.42 ± 0.000	6.98 ± 0.023	5.27 ± 0.02	48
LT14-(5-6)	5-6	5.5	2.2500	6	255885	6229	9278	0.00 ± 1.52E-05	0.0034 ± 1.81E-05	1.46 ± 0.019	2.17 ± 0.000	6.69 ± 0.019	4.98 ± 0.02	72
LT14-(6-7)	6-7	6.5	2.3200	7	256061	6381	10020	0.00 ± 2.07E-05	0.0017 ± 1.28E-05	1.49 ± 0.019	2.35 ± 0.000	6.85 ± 0.020	5.14 ± 0.02	74
LT14-(7-8)	7-8	7.5	1.5500	8	254236	6241	5999	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	1.47 ± 0.019	1.41 ± 0.000	6.28 ± 0.012	4.57 ± 0.01	73
LT14-(8-9)	8-9	8.5	2.3900	9	253666	6476	8601	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.53 ± 0.019	2.03 ± 0.000	5.62 ± 0.017	3.91 ± 0.02	76
LT14-(9-10)	9-10	9.5	1.8500	10	253824	3095	2644	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	0.73 ± 0.013	0.62 ± 0.000	4.67 ± 0.015	2.96 ± 0.02	36
LT14-(10-11)	10-11	10.5	2.3100	11	254703	5900	6816	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.39 ± 0.018	1.60 ± 0.000	5.06 ± 0.015	3.35 ± 0.02	69
LT14-(11-12)	11-12	11.5	1.7300	12	254789	6076	5735	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.43 ± 0.018	1.35 ± 0.000	5.52 ± 0.012	3.81 ± 0.01	71
LT14-13	12-13	12.5	0.9749	9	140323	2905	1325	0.00 ± 7.50E-06	0.0012 ± 4.43E-06	1.24 ± 0.023	0.57 ± 0.000	4.73 ± 0.008	3.02 ± 0.01	61
LT14-14	13-14	13.5	0.3613	10	140295	3968	585	0.00 ± 7.31E-06	0.0023 ± 6.12E-06	1.69 ± 0.027	0.25 ± 0.000	4.09 ± 0.002	2.38 ± 0.00	84
LT14-17	16-17	16.5	0.3345	19	173466	3226	599	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	1.11 ± 0.020	0.21 ± 0.000	5.59 ± 0.003	3.88 ± 0.00	55
LT14-18	17-18	17.5	0.4559	11	140287	3220	494	0.00 ± 7.11E-06	0.0021 ± 5.89E-06	1.37 ± 0.024	0.21 ± 0.000	3.37 ± 0.003	1.66 ± 0.00	68
LT14-19	18-19	18.5	0.2695	8	140301	2083	169	0.01 ± 9.33E-06	0.0011 ± 4.22E-06	0.89 ± 0.020	0.07 ± 0.000	3.01 ± 0.002	1.30 ± 0.00	44
LT14-19	18-19	18.5	0.2695	20	173470	3011	267	0.00 ± 4.64E-06	0.0013 ± 4.64E-06	1.04 ± 0.019	0.09 ± 0.000	3.28 ± 0.002	1.57 ± 0.00	52
LT14-20	19-20	19.5	0.4643	12	140267	2503	320	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.07 ± 0.021	0.14 ± 0.000	2.76 ± 0.003	1.05 ± 0.00	53
LT14-21	24-25	24.5	0.6755	13	140268	2550	455	0.01 ± 1.17E-05	0.0036 ± 7.62E-06	1.08 ± 0.022	0.19 ± 0.000	2.64 ± 0.004	0.93 ± 0.00	54
LT14-(39-40)	39-40	39.5	1.5500	12	142666	2122	630	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.89 ± 0.019	0.26 ± 0.000	1.74 ± 0.006	0.03 ± 0.01	44
LT14-(44-45)	44-45	44.5	2.0700	13	142666	2987	1297	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	1.25 ± 0.023	0.54 ± 0.000	1.69 ± 0.008		62
LT14-27	54-55	54.5	0.4679	14	140253	3055	266	0.01 ± 1.28E-05	0.0204 ± 1.82E-05	1.30 ± 0.024	0.09 ± 0.000	1.55 ± 0.001		64
LT14-28	59-60	59.5	0.7165	15	140216	2647	347	0.01 ± 1.33E-05	0.0078 ± 1.12E-05	1.12 ± 0.022	0.14 ± 0.000	1.77 ± 0.002		56
LT14-29	64-65	64.5	0.6436	19	107936	2600	261	0.00 ± 6.63E-06	0.0011 ± 4.22E-06	1.44 ± 0.028	0.14 ± 0.000	1.57 ± 0.002		71
LT14-(69-70)	69-70	69.5	2.0800	14	193241	1833	498	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.57 ± 0.013	0.15 ± 0.000	1.31 ± 0.006		28
LT14-(74-75)	74-75	74.5	2.0100	15	192005	1899	639	0.00 ± 7.50E-06	0.0015 ± 4.84E-06	0.59 ± 0.014	0.20 ± 0.000	1.69 ± 0.008		29

APPENDIX 3A Sedimentologic and paleontologic (except pollen) raw data

Core LT-
98-2M
Lubulungu Delta

Flux Factor	Depth	Wet Weight	Dry Weight	Water Content	>1 mm	>106 _m	>63 _m	<63 _m	CO3	Organic Matter	Ostracode Specimens Count	Number of Species	Fisher's-a Diversity index	Jaccard's Similarity Index	Ostracode Population	Ostracode Flux	Sponge Spicules	Sponge Flux	Molluscs	Mollusc Flux	Fish Bones	Fish Bone Flux	Charcoal	Charcoal Flux
	(cm)	(g)	(g)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(#)	(#)	(a)		(#/g)		(#/g)		(#/g)		(#/g)		(#/g)	
0.8	0.5	4.3	1.556	63.814	0.321	7.969	9.576	82.13	2.000	13.897	306	22	5.43	0.33	197	157	6	5	10	8	6	5	4756	3805
0.8	3.5	15.72	4.99	68.257	3.327	4.649	2.926	89.1	2.504	15.019	1857	26	4.28	0.44	372	298	18	14	116	93	32	26	1179	943
0.34	6.5	17.9	5.341	70.162	2.528	6.459	3.894	87.12	2.372	15.787	968	24	4.46	0.48	181	62	22	7	38	13	25	9	1730	588
0.34	9.5	14.83	3.993	73.075	0.150	3.431	1.678	94.74	2.312	13.824	948	28	5.42	0.25	237	81	36	12	20	7	36	12	349	119
0.34	12.5	19.95	6.362	68.110	0.613	4.558	1.226	93.6	5.276	15.256	663	34	7.59	0.38	104	35	62	21	11	4	31	11	1931	656
0.34	15.5	15.78	5.237	66.812	0.267	8.001	0.707	91.03	5.218	14.138	415	33	8.42	0.45	79	27	33	11	21	7	11	4	520	177
0.34	18.5	20.03	6.518	67.459	5.646	10.893	2.194	81.27	7.581	10.466	519	34	8.16	0.35	80	27	108	37	25	9	40	14	303	103
0.08	21.5	17.91	7.152	60.067	0.545	4.656	1.888	92.91	3.748	14.233	567	34	7.94	0.56	79	6	71	6	28	2	61	5	499	40
0.08	24.5	20.84	9.665	53.623	0.124	4.118	1.438	94.32	2.024	13.591	334	25	6.26	0.29	35	3	82	7	43	3	74	6	339	27
0.08	27.5	21.15	9.197	56.515	0.130	9.144	22.594	68.13	2.427	14.082	44	14	7.09		5	0.4	88	7	0	0	124	10	49	4
0.08	29.5	17.18	5.406	68.533	0.314	11.487	3.626	84.57	2.596	14.032	0	0	0		0		72	6	0	0	59	5	53	4
0.08	30.5	22.38	7.693	65.626	0.234	19.927	4.160	75.68	2.738	12.761	0	0	0		0		30	2	0	0	115	9	316	25
0.08	33.5	19.39	6.526	66.343	0.061	15.323	7.371	77.25	1.784	12.605	0	0	0		0		63	5	0	0	36	3	102	8
0.04	36.5	26.76	14.045	47.515	2.214	64.543	3.382	29.86	0.869	4.578	0	0	0		0		150	6	0	0	216	9	56	2
0.04	39.5	30.83	17.835	42.151	1.918	60.712	4.631	32.74	0.805	4.597	0	0	0		0		301	12	0	0	54	2	35	1
0.04	42.5	27.51	17.459	36.536	1.621	61.739	5.911	30.73	0.746	3.400	0	0	0		0		455	18	0	0	86	3	41	2
0.04	45.5	23.75	16.44	30.779	2.196	69.763	5.566	22.48	0.818	2.541	0	0	0		0		426	17	0	0	73	3	167	7
0.04	48.5	35.42	23.38	33.992	2.361	68.713	5.620	23.31	0.561	3.476	0	0	0		0		591	24	0	0	75	3	9	0.38

APPENDIX 3B Sedimentologic and paleontologic (except pollen) raw data

CORE
LT-98-
12M
Lubulungu Delta

Flux Factor	Depth	Wet Weight	Dry Weight	Water Content	>1 mm	>106 mm	>63 mm	<63 mm	CO3	Organic Matter	Ostracode Specimens Count	Number of Species	Fisher's-a Diversity index	Jaccard's Similarity Index	Ostracode Population	Ostracode Flux	Sponge Spicules	Sponge Flux	Molluscs	Mollusc Flux	Fish Bones	Fish Bones Flux	Charcoal	Charcoal Flux
	(cm)	(g)	(g)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(#)	(#)	(a)		(#/g)		(#/g)		(#/g)		(#/g)		(#/g)	
0.6	0.5	13.038	2.634	79.798	0.000	10.213	4.973	78.094	1.965	16.532	50	23	16.50	0.40	19	11	1898	1139	0	0	3	2	4935	2961
0.6	3.5	20.027	5.547	72.302	0.108	11.826	5.733	74.995	3.026	14.627	93	36	21.55	0.36	17	10	98	59	0	0	9	5	1726	1036
0.6	6.5	18.291	7.212	60.571	0.042	9.526	6.780	82.945	1.850	12.949	75	25	13.13	0.63	10	6	123	74	5	3	7	4	1477	886
0.6	9.5	19.54	6.25	68.014	0.064	4.672	1.840	90.64	1.440	13.285	98	32	16.53	0.49	16	9	142	85	46	28	39	23	3738	2243
0.6	12.5	14.676	4.164	71.627	0.048	3.842	4.251	87.968	2.821	15.484	111	32	15.06	0.38	27	16	1210	726	23	14	20	12	1861	1117
0.6	15.5	18.905	4.829	74.456	0.000	3.106	6.772	88.176	1.702	14.499	27	15	13.90	0.48	6	3	327	196	13	8	17	10	736	441
0.6	18.5	19.904	4.197	78.914	0.000	1.549	0.071	92.9	2.730	14.566	30	16	13.93	0.41	7	4	0	0	9	5	16	10	871	523
0.6	21.5	13.639	3.721	72.718	0.027	3.359	2.526	89.895	2.714	13.505	34	15	10.26	0.35	9	5	267	160	0	0	0	0	2532	1519
0.6	24.5	17.222	4.397	74.469	0.159	1.319	2.866	90.835	2.761	13.388	29	16	14.66	0.22	7	4	1137	682	7	4	11	7	1535	921
0.6	27.5	18.647	4.404	76.382	0.068	4.587	2.679	86.512	3.087	13.619	37	17	12.18	0.14	8	5	1135	681	37	22	21	13	2715	1629
0.6	30.5	21.432	5.995	72.028	0.050	3.136	1.118	91.693	2.921	13.624	13	8	8.85	0.11	2	1	8340	5004	42	25	51	31	5106	3064
0.6	33.5	14.209	3.348	76.437	0.000	1.912	3.823	92.324	2.831	13.801	27	12	8.28	0.29	8	5	1493	896	13	8	31	19	5580	3348
0.6	36.5	16.991	4.241	75.040	0.118	0.307	0.354	97.265	1.580	13.871	19	10	8.54	0.18	4	3	11790	7074	21	13	23	14	5983	3590
0.6	37.5	12.297	3.083	74.929	0.357	1.297	4.411	91.923	3.023	14.212	14	10	14.25		5	3	1622	973	36	22	27	16	6163	3698

APPENDIX 3C Sedimentologic and paleontologic (except pollen) raw data

CORE LT-98-18M

Kabesi Delta

Stratigraphic level (cm.)	Water content (wt.%)	Silt+Clay (wt.%)	LOI-CO3 (wt.%)	LOI-TOC (wt.%)	Ostracode Pop (#/g)	Ostracode Flux	Fisher's Alpha	Jaccard Index	Sponge Spicules (#/g)	Sponge Spicule Flux	Charcoal (#/g)	Charcoal Flux	% Adults	% Frag valves	% Carapaces
0.5	59.384	97.519	1.966	7.99	702.88	2460	2.67	0.4545	435.0382	1522.63	14.4621	50.6173	0	12.8	0
3.5	55.123	98.551	1.759	8.159	2380.5	8332	3.65	0.3929	548.5407	1919.89	235.665	824.829	0.6	13.6	0.8
6.5	61.667	99.036	1.606	8.602	2650	9275	4.44	0.3611	149.1339	521.969	236.893	829.127	2.4	14.3	3.6
9.5	62.676	98.754	2.044	9.071	1130.8	3958	6.41	0.4474	276.2786	966.975	280.776	982.717	1.4	14.6	2.8
12.5	64.654	99.046	2.515	9.887	598.44	2095	6.11	0.4054	215.0911	752.819	315.872	1105.55	2.2	27.8	3.6
15.5	61.645	99.271	2.365	10.272	353.77	389	5.54	0.3514	187.6072	206.368	0	0	0	16.1	1.6
18.5	63.361	99.387	2.228	10.4	390.3	429	5.54	0.3721	139.3922	153.331	330.36	363.396	0	8.9	1.2
21.5	66.265	99.464	1.423	12.258	38.049	42	10.02	0.3913	37.77473	41.5522	301.923	332.115	27.1	45.9	6.25
24.5	64.782	99.309	1.341	12.022	40.005	44	10.23	0.3922	65.15507	71.6706	373.599	410.959	2.2	41.4	1.3
27.5	75.38	98.770	1.765	11.614	112.28	157	10.58	0.5	169.3103	237.034	508.287	711.602	35.4	31.8	4.8
30.5	75.284	99.552	1.748	11.194	132.22	185	10.23	0.5227	213.5883	299.024	827.502	1158.5	36.7	35.4	4
33.5	76.128	99.129	1.625	11.489	181.42	254	6.11	0.4	816.4006	1142.96	987.482	1382.47	30	34	3.2
36.5	74.276	99.235	1.700	11.552	142.72	200	8.9	0.4889	1372.28	1921.19	1076.06	1506.49	30.9	33.2	3.6
39.5	71.521	99.178	1.687	10.94	114.84	161	7.31		893.0166	1250.22	924.987	1294.98	45.3	33.3	0.8

APPENDIX 3D Sedimentologic and paleontologic (except pollen) raw data

CORE
LT-98-
58M
Gombe Area

Flux Factor	Depth (cm)	Wet Weight (g)	Dry Weight (g)	Water Content (Wt. %)	>1 mm (Wt. %)	>106 mm (Wt. %)	>63 mm (Wt. %)	<63 mm (Wt. %)	CO3 (Wt. %)	Organic Matter (Wt. %)	Ostracode Specimens Count (#)	Number of Species (#)	Fisher's-a Diversity index (a)	Jaccard's Similarity Index	Ostracode Population (#/g)	Ostracode Flux	Sponge Spicules (#/g)	Sponge Flux	Molluscs (#/g)	Mollusc Flux	Fish Bones (#/g)	Fish Bones Flux	Charcoal (#/g)	Charcoal Flux
1.5	0.5	16.890	7.520	55.477	0.013	2.832	9.495	87.660	14.810	7.970	500	41	10.58	0.52	283	425	16	24	0	0	11	17	19473	29210
1.5	3.5	20.710	10.687	48.397	0.019	5.390	12.015	82.577	10.300	6.453	500	47	12.71	0.76	539	808	137	206	1	2	9	14	8855	13282
1.5	6.5	17.610	7.794	55.741	0.013	2.002	6.107	91.878	11.483	8.707	500	43	11.27	0.57	200	300	297	446	3	5	13	20	4876	7313
1.5	9.5	18.570	9.825	47.600	0.010	1.221	5.150	93.618	6.277	8.709	500	40	10.23	0.63	122	183	189	284	0	0	3	5	3257	4885
1.5	12.5	20.420	11.867	41.885	0.008	9.337	17.789	72.866	2.661	7.014	500	40	10.23	0.66	934	1401	37	56	0	0	7	11	6669	10004
1.5	15.5	18.390	10.852	40.990	0.009	0.461	4.736	94.794	3.172	6.231	500	33	7.93	0.73	46	69	6	9	3	5	12	18	3225	4838
1.5	18.5	24.430	12.432	49.112	0.008	0.265	1.375	98.351	3.523	6.010	500	38	9.56	0.64	27	40	89	134	0	0	9	14	2574	3861
1.5	21.5	18.050	9.240	48.809	0.011	0.444	2.446	97.100	5.218	6.335	500	39	9.89	0.64	44	67	113	170	4	6	12	18	3355	5032
1.5	24.5	20.390	9.903	51.432	0.010	0.980	2.838	96.173	16.245	7.336	500	35	8.57	0.78	98	147	127	191	0	0	6	9	4039	6059
1.5	27.5	17.220	8.263	52.015	0.012	1.392	4.308	94.288	13.344	7.390	500	36	8.90	0.60	139	209	113	170	0	0	9	14	10118	15178
1.5	30.5	15.870	6.713	57.700	0.015	3.486	7.999	88.500	3.576	8.295	500	36	8.90	0.67	349	523	99	149	0	0	6	9	16884	25326
1.5	33.5	15.700	5.502	64.955	0.036	2.054	5.307	92.603	7.882	8.037	500	36	8.90	0.71	205	308	6649	9973	0	0	11	17	7567	11350
1.5	36.5	18.040	8.507	52.844	0.012	2.762	4.808	92.418	10.217	7.917	500	34	8.25	0.62	276	414	4679	7018	0	0	4	6	9000	13500
1.5	37.5	24.360	12.231	49.791	0.041	2.019	4.791	93.149	8.820	7.698	500	34	8.25		202	303	89	134	1	2	3	5	8466	12699

APPENDIX 3E Sedimentologic and paleontologic (except pollen) raw data

CORE LT-98-37M
Mwamgongo Delta

Flux Factor	Depth (cm)	Wet Weight (g)	Dry Weight (g)	Water Content (Wt. %)	>1 mm (Wt. %)	>106 µm (Wt. %)	>63 µm (Wt. %)	<63 µm (Wt. %)	CO3 (Wt. %)	Organic Matter (Wt. %)	Ostracode Specimens Count (#)	Number of Species (#)	Fisher's-a Diversity index (a)	Jaccard's Similarity Index	Ostracode Population (#/g)	Ostracode Flux	Sponge Spicules (#/g)	Sponge Flux	Molluscs (#/g)	Mollusc Flux	Fish Bones (#/g)	Fish Bones Flux	Charcoal
1.2	0.5	9.78	2.051	79.029	0.049	0.780	1.511	97.66	2.431	10.042	350	37	10.45	0.53	171	205	297	356	1	1	17	20	
1.2	3.5	19.23	6.934	63.942	0.087	0.404	0.923	98.587	2.240	9.851	500	34	8.25	0.64	404	485	51	61	3	4	5	6	
1.2	6.5	24.19	7.450	69.202	0.081	0.470	1.477	97.973	3.658	17.311	500	34	8.25	0.53	470	564	67	80	3	4	5	6	
1.2	9.5	18.21	6.164	66.150	0.016	0.438	1.282	98.264	14.993	10.917	500	35	8.57	0.60	438	526	21	25	0	0	0	0	
1.2	12.5	18.93	7.511	60.322	0.013	0.626	1.318	98.043	30.201	7.471	500	40	10.23	0.51	626	751	18	22	0	0	1	1	
1.2	15.5	22.55	8.763	61.140	0.011	0.388	1.312	98.288	26.526	8.189	500	41	10.58	0.71	388	466	17	20	0	0	7	8	
1.2	18.5	17.98	8.018	55.406	0.012	0.549	1.596	97.842	29.771	6.978	500	32	7.62	0.76	549	659	0	0	0	0	21	25	
1.2	21.5	22.10	8.760	60.362	0.023	0.525	1.016	98.436	19.222	7.692	500	35	8.57	0.74	525	630	0	0	0	0	29	35	
0.5	24.5	21.80	8.197	62.399	0.012	0.415	0.281	99.292	10.827	8.846	500	40	10.23	0.58	415	207	1	1	0	0	21	11	
0.5	27.5	22.11	9.240	58.209	0.011	0.563	1.396	98.03	14.799	8.701	500	36	8.90	0.62	563	281	13	7	0	0	17	9	
0.5	30.5	23.84	8.998	62.257	0.011	1.800	3.890	94.299	12.800	10.014	500	37	9.22	0.64	1800	900	7	4	0	0	6	3	
0.5	33.5	23.37	8.276	64.587	0.012	1.595	3.420	94.973	21.197	9.433	500	37	9.22	0.70	1595	797	0	0	0	0	0	0	
0.5	36.5	20.72	8.752	57.761	0.023	1.485	3.165	95.327	17.915	10.090	500	36	8.9	0.71	1485	743	0	0	0	0	7	4	
0.5	39.5	21.66	9.105	57.964	0.011	1.219	2.164	96.606	25.804	9.126	500	36	8.9	0.74	1219	610	0	0	0	0	13	7	
0.5	42.5	20.82	7.202	65.408	0.014	4.054	5.096	90.836	8.744	12.059	500	37	9.22	0.67	4054	2027	0	0	0	0	16	8	
0.5	43.5	22.70	8.806	61.207	0.045	4.917	5.701	89.337	8.136	11.995	500	35	8.57		4917	2459	0	0	0	0	6	3	

APPENDIX 3F Sedimentologic and paleontologic (except pollen) raw data

CORE
LT-98-
98A
Nyamusenyi
Delta

Flux Factor	Depth	Wet Weight	Dry Weight	Water Content	>1 mm	>106 mm	>63 mm	<63 mm	CO3	Organic Matter	Ostracode Specimens Count	Number of Species	Fisher's-a Diversity index	Jaccard's Similarity Index	Ostracode Population	Ostracode Flux	Sponge Spicules	Sponge Flux	Molluscs	Mollusc Flux	Fish Bones	Fish Bones Flux	Charcoal	Charcoal Flux
N/A	(cm)	(g)	(g)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(Wt. %)	(#)	(#)	(a)		(#/g)		(#/g)		(#/g)		(#/g)		(#/g)	
	0.5	13.170	6.435	51.139	0.016	10.505	13.986	75.493	1.656	7.070	142	31	12.23	0.09	22		3		6		11		639	
	3.5	14.490	8.003	44.769	0.037	17.468	12.920	69.574	1.710	7.346	17	6	3.31		2		0		2		3		694	
	6.5	12.630	6.170	51.148	0.016	7.293	13.290	79.400	1.386	8.958	0	0			0		0		0		0		2987	
	9.5	24.150	14.836	38.567	0.411	45.969	14.600	39.020	1.295	6.463	0	0			0		0		0		0		6530	
	12.5	21.750	12.310	43.402	0.089	15.459	14.582	69.870	1.342	8.496	0	0			0		0		0		0		2673	
	15.5	22.460	12.760	43.188	0.149	18.605	19.976	61.270	1.633	6.992	0	0			0		0		0		0		13461	
	18.5	17.000	9.528	43.953	0.367	13.770	17.695	68.168	1.577	7.476	0	0			0		0		0		0		5282	
	21.5	18.940	9.579	49.426	0.031	28.292	11.857	59.820	1.583	4.657	0	0			0		0		0		0		5805	
	24.5	19.550	10.201	47.821	0.010	14.528	12.156	73.307	2.040	7.626	0	0			0		0		0		0		5130	
	27.5	22.320	11.591	48.069	0.026	15.883	14.822	69.269	1.859	8.137	0	0			0		0		0		0		4671	
	30.5	21.140	12.049	43.004	0.116	29.621	16.873	53.390	1.664	6.883	0	0			0		0		0		0		5766	
	33.5	20.080	11.055	44.945	0.027	11.226	20.244	68.503	1.620	7.620	0	0			0		0		0		0		5426	
	34.5	19.300	10.915	43.446	0.018	10.041	13.175	76.766	1.763	7.866	0	0			0		0		0		0		3798	
	36.5	17.910	12.345	31.072	0.008	63.200	18.996	17.797	1.622	2.844	0	0			0		0		0		0		5225	

APPENDIX 3G Sedimentologic and paleontologic (except pollen) raw data

CORE LT-98-
82 M
Karonge/Kirasa Deltas

Flux Factor	Depth (cm)	Wet Weight (g)	Dry Weight (g)	Water Content (Wt. %)	>1 mm (Wt. %)	>106 µm (Wt. %)	>63 µm (Wt. %)	<63 µm (Wt. %)	CO3 (Wt. %)	Organic Matter (Wt. %)	Specimens Count (#)	Number of Species (#)	Fisher's-a Diversity (a)	Jaccard's Similarity	Ostracode Population (#/g)	Ostracode Flux	Sponge Spicules (#/g)	Sponge Flux	Molluscs (#/g)	Mollusc Flux	Fish Bones (#/g)	Fish Bones Flux	Charcoal (#/g)	Charcoal Flux
9	0.5	17.63	2.69	84.765	0.000	0.633	0.633	98.734	2.437	13.205	0	0	0	0	0	0	0	0	0	0	0	0	1115	10037
9	3.5	16.79	3.78	77.481	0.000	0.132	0.899	98.969	2.128	12.770	0	0	0	0	0	0	199	1791	0	0	0	0	529	4762
9	6.5	22.26	4.97	77.691	0.000	2.316	0.443	97.241	2.196	12.251	0	0	0	0	0	0	139	1251	0	0	7	63	80	724
9	9.5	18.54	4.19	77.384	0.000	1.622	0.835	97.544	2.384	11.262	0	0	0	0	0	0	23	207	0	0	0	0	72	644
3.2	12.5	16.91	3.72	78.019	0.000	2.529	0.915	96.556	2.246	13.257	0	0	0	0	0	0	362	1158	0	0	0	0	269	860
3.2	15.5	17.31	2.82	83.709	0.035	0.993	0.922	98.050	2.745	13.272	0	0	0	0	0	0	351	1123	0	0	0	0	674	2156
0.8	18.5	13.46	3.3	75.505	0.000	0.485	1.031	98.483	2.561	13.094	0	0	0	0	0	0	507	406	0	0	0	0	727	582
0.8	21.5	20.92	4.37	79.120	0.000	1.305	0.824	97.871	2.711	12.008	0	0	0	0	0	0	506	405	0	0	0	0	481	384
2.3	24.5	16.61	4.97	70.096	0.000	1.007	1.289	97.705	2.678	11.937	0	0	0	0	0	0	352	810	0	0	0	0	262	602
2.3	27.5	20.91	5.03	75.945	0.020	0.974	1.690	97.316	2.772	13.985	39	15	8.92	0.48	8	18	152	350	0	0	10	23	2386	5487
2.3	30.5	18.67	4.13	77.906	0.024	1.939	2.448	95.588	3.424	13.469	35	16	11.40	0.33	8	19	131	301	0	0	8	18	1211	2785
2.3	33.5	19.91	4.82	75.811	0.062	0.789	2.429	96.719	4.201	13.831	32	12	6.97	0.18	7	15	107	246	0	0	11	25	1743	4008
2.3	36.5	19.6	3.99	79.638	0.025	1.804	1.453	96.718	8.300	13.062	13	8	8.85	0.10	3	7	18	41	1	2	6	14	877	2018
1	39.5	21.95	4.92	77.581	0.020	1.585	2.703	95.692	2.769	14.746	31	14	9.83	0.25	6	6	70	70	0	0	14	14	976	976
1	40.5	21.1	5.2	75.379	0.154	2.175	2.656	95.014	2.682	13.722	48	26	23.17	0.30	9	9	102	102	0	0	7	7	1365	1365
1	42.5	21.83	5.16	76.363	0.000	2.229	3.217	94.554	2.527	13.362	25	13	10.92	0.07	5	5	62	62	0	0	3	3	872	872
1	44.5	19.1	5.05	73.571	0.000	2.912	1.446	95.642	3.425	12.719	6	3	2.39		1	1	52	52	0	0	0	0	594	594

Appendix 5: Palynology data

Table 5a: Core LT-98-2M (pollen counts and percentages for the taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	*Acalypha*	*Alchornea*	*Amaran/Chen*	*Isoberlinia*	*Artemisia*	*Brachystegia*	*Commiphora*	*Celtis*	*Commelina*	*Cyperaceae*	*Croton*	*Euphorbiaceae*	*Gramineae*	*Holoptelea grandis*	*Ilex*	*Liliaceae*	*Macaranga*	*Mallotus*	*Moracea*	*Myrica*	*Myrtaceae*	*Oleaceae*	*Other Compositae*	*Podocarpus*	*Polygonaceae*	*Polypodium*	*Proteac./Sapind.*	*Ranunculaceae*	*Rosacea*	*Rubiacea*	*Typha*	Pteridophyte spore	Renif. Fern spore	Hindered/Crumped	Unidentified	Total counts*/%
1	0-1	5	2	1	0	15	2	0	1	2	11	1	4	197	0	5	0	0	1	0	1	0	11	10	1	1	7	0	2	1	0	0	14	0	9	8	315
		1.59	0.63	0.32	0.00	4.76	0.63	0.00	0.32	0.63	3.49	0.32	1.27	62.54	0.00	1.59	0.00	0.00	0.32	0.00	0.32	0.00	3.49	3.17	0.32	0.32	2.22	0.00	0.63	0.32	0.00	0.00	4.44	0.00	2.86	2.54	100
2	3-4	0	2	1	0	1	2	1	3	1	12	0	3	348	0	0	1	0	1	2	0	1	5	3	1	0	9	0	3	1	0	0	9	3	11	19	447
		0.00	0.45	0.22	0.00	0.22	0.45	0.22	0.67	0.22	2.68	0.00	0.67	77.85	0.00	0.00	0.22	0.00	0.22	0.45	0.00	0.22	1.12	0.67	0.22	0.00	2.01	0.00	0.67	0.22	0.00	0.00	2.01	0.67	2.46	4.25	100
3	6-7	0	0	4	0	13	4	1	3	1	16	2	3	347	0	1	1	3	1	0	0	0	7	6	2	0	1	1	0	1	0	3	28	9	18	21	500
		0	0	0.8	0	2.6	0.8	0.2	0.6	0.2	3.2	0.4	0.6	69.4	0	0.2	0.2	0.6	0.2	0	0	0	1.4	1.2	0.4	0	0.2	0.2	0	0.2	0	0.6	5.6	1.8	3.6	4.2	100
4	9-10	1	1	0	0	17	0	1	0	0	12	0	8	248	0	0	0	2	1	4	0	0	3	13	7	0	10	0	2	0	0	0	2	3	13	14	364
		0.27	0.27	0.00	0.00	4.67	0.00	0.27	0.00	0.00	3.30	0.00	2.20	68.13	0.00	0.00	0.00	0.55	0.27	1.10	0.00	0.00	0.82	3.57	1.92	0.00	2.75	0.00	0.55	0.00	0.00	0.00	0.55	0.82	3.57	3.85	100
5	12-13	0	1	2	0	9	0	0	1	0	4	1	0	395	0	0	2	1	0	0	1	0	6	6	4	0	0	0	1	1	0	2	6	1	17	10	480
		0.00	0.21	0.42	0.00	1.88	0.00	0.00	0.21	0.00	0.83	0.21	0.00	82.29	0.00	0.00	0.42	0.21	0.00	0.00	0.21	0.00	1.25	1.25	0.83	0.00	0.00	0.00	0.21	0.21	0.00	0.42	1.25	0.21	3.54	2.08	100
6	15-16	0	1	0	0	1	0	0	1	6	4	0	1	246	0	0	1	0	0	1	0	0	9	1	0	0	11	0	5	0	0	3	4	2	15	17	334
		0.00	0.30	0.00	0.00	0.30	0.00	0.00	0.30	1.80	1.20	0.00	0.30	73.65	0.00	0.00	0.30	0.00	0.00	0.30	0.00	0.00	2.69	0.30	0.00	0.00	3.29	0.00	1.50	0.00	0.00	0.90	1.20	0.60	4.49	5.09	100
7	18-19	0	1	1	0	15	2	0	0	0	13	0	4	300	0	0	1	0	0	0	0	0	0	15	4	0	8	1	0	1	0	0	5	0	10	14	402
		0.00	0.25	0.25	0.00	3.73	0.50	0.00	0.00	0.00	3.23	0.00	1.00	74.63	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	3.73	1.00	0.00	1.99	0.25	0.00	0.25	0.00	0.00	1.24	0.00	2.49	3.48	100
8	21-22	0	2	1	0	13	0	0	0	0	5	1	0	223	0	0	0	0	0	0	0	0	13	5	7	0	9	0	0	1	0	2	12	1	9	10	316
		0.00	0.63	0.32	0.00	4.11	0.00	0.00	0.00	0.00	1.58	0.32	0.00	70.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.11	1.58	2.22	0.00	2.85	0.00	0.00	0.32	0.00	0.63	3.80	0.32	2.85	3.16	100
9	24-25	0	1	4	0	8	2	0	0	0	6	2	7	439	0	0	0	1	0	0	1	1	15	12	13	0	10	0	0	3	0	0	11	6	17	8	580
		0.00	0.17	0.69	0.00	1.38	0.34	0.00	0.00	0.00	1.03	0.34	1.21	75.69	0.00	0.00	0.00	0.17	0.00	0.00	0.17	0.17	2.59	2.07	2.24	0.00	1.72	0.00	0.00	0.52	0.00	0.00	1.90	1.03	2.93	1.38	100
10	27-28	4	4	2	3	11	3	1	0	1	3	8	10	298	3	0	4	1	0	1	0	0	12	2	16	0	6	1	1	7	0	0	4	2	17	4	510
		0.78	0.78	0.39	0.59	2.16	0.59	0.20	0.00	0.20	0.59	1.57	1.96	58.43	0.59	0.00	0.78	0.20	0.00	0.20	0.00	0.00	2.35	0.39	3.14	0.00	1.18	0.20	0.20	1.37	0.00	0.00	0.78	0.39	3.33	0.78	100
11	29-30	1	3	1	6	16	1	4	0	2	10	3	21	301	3	1	6	2	0	2	0	0	22	11	18	1	12	0	5	7	1	3	5	0	23	10	443
		0.23	0.68	0.23	1.35	3.61	0.23	0.90	0.00	0.45	2.26	0.68	4.74	67.95	0.68	0.23	1.35	0.45	0.00	0.45	0.00	0.00	4.97	2.48	4.06	0.23	2.71	0.00	1.13	1.58	0.23	0.68	1.13	0.00	5.19	2.26	100
12	30-31	5	2	1	1	11	1	3	3	3	12	2	7	330	1	1	9	1	0	5	1	1	15	5	19	0	24	1	0	11	4	3	6	0	6	8	520
		0.96	0.38	0.19	0.19	2.12	0.19	0.58	0.58	0.58	2.31	0.38	1.35	63.46	0.19	0.19	1.73	0.19	0.00	0.96	0.19	0.19	2.88	0.96	3.65	0.00	4.62	0.19	0.00	2.12	0.77	0.58	1.15	0.00	1.15	1.54	100
13	33-34	1	3	1	2	5	3	0	0	0	7	2	0	245	3	14	10	0	0	0	0	0	15	6	32	0	15	1	0	9	0	5	8	1	14	17	451
		0.22	0.67	0.22	0.44	1.11	0.67	0.00	0.00	0.00	1.55	0.44	0.00	54.32	0.67	3.10	2.22	0.00	0.00	0.00	0.00	0.00	3.33	1.33	7.10	0.00	3.33	0.22	0.00	2.00	0.00	1.11	1.77	0.22	3.10	3.77	100
14	36-37	1	7	1	0	8	10	2	7	4	11	3	13	313	1	0	6	3	1	0	0	0	21	3	13	0	16	2	1	10	3	9	3	2	5	16	512
		0.20	1.37	0.20	0.00	1.56	1.95	0.39	1.37	0.78	2.15	0.59	2.54	61.13	0.20	0.00	1.17	0.59	0.20	0.00	0.00	0.00	4.10	0.59	2.54	0.00	3.13	0.39	0.20	1.95	0.59	1.76	0.59	0.39	0.98	3.13	100
15	39-40	1	8	1	2	4	3	1	7	1	8	2	10	332	1	2	2	3	1	4	3	0	21	5	9	0	28	0	0	10	3	1	11	4	16	11	529
		0.19	1.51	0.19	0.38	0.76	0.57	0.19	1.32	0.19	1.51	0.38	1.89	62.76	0.19	0.38	0.38	0.57	0.19	0.76	0.57	0.00	3.97	0.95	1.70	0.00	5.29	0.00	0.00	1.89	0.57	0.19	2.08	0.76	3.02	2.08	100
16	42-43	3	3	2	3	3	1	3	4	6	4	3	8	221	2	0	6	2	1	0	1	0	17	2	6	0	5	0	0	10	1	4	4	5	6	12	353
		0.85	0.85	0.57	0.85	0.85	0.28	0.85	1.13	1.70	1.13	0.85	2.27	62.61	0.57	0.00	1.70	0.57	0.28	0.00	0.28	0.00	4.82	0.57	1.70	0.00	1.42	0.00	0.00	2.83	0.28	1.13	1.13	1.42	1.70	3.40	100
17	45-46	4	3	2	2	3	1	1	2	4	16	1	4	283	1	2	3	1	2	0	3	0	27	6	9	0	16	0	0	13	1	2	2	4	13	10	454
		0.88	0.66	0.44	0.44	0.66	0.22	0.22	0.44	0.88	3.52	0.22	0.88	62.33	0.22	0.44	0.66	0.22	0.44	0.00	0.66	0.00	5.95	1.32	1.98	0.00	3.52	0.00	0.00	2.86	0.22	0.44	0.44	0.88	2.86	2.20	100
18	48-49	1	1	1	3	1	3	0	18	0	7	1	15	208	2	3	6	1	2	0	0	0	18	5	12	2	8	1	0	10	3	2	12	6	20	12	395
		0.25	0.25	0.25	0.76	0.25	0.76	0.00	4.56	0.00	1.77	0.25	3.80	52.66	0.51	0.76	1.52	0.25	0.51	0.00	0.00	0.00	4.56	1.27	3.04	0.51	2.03	0.25	0.00	2.53	0.76	0.51	3.04	1.52	5.06	3.04	100

Table 5b: Core LT-98-12M (pollen counts ad percentages for the taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	Acacia	*Acalypha*	*Acanthaceae*	*Alchornea*	*Amaran/Chen*	*Isoberlinia*	*Bignoniaceae*	*Brachystegia*	*Combretaceae*	*Commiphora*	*Celtis*	*Commelina*	*Cyperaceae*	*Croton*	*Euphorbiaceae*	*Gentianaceae*	*Gramineae*	*Holoptelea grandis*	*Liliaceae*	*Macaranga*	*Mallotus*	*Moracea*	*Myrica*	*Myrtaceae*	*Oleaceae*	*Other Compositae*	*Podocarpus*	*Polypodium*	*Proteac./Sapind*	*Typha*	Pteridophyte spore	Renif. Fern spore	Hindered/Crumped	Unidentified	Total counts*/%
1	0-1	1	16	2	9	7	0	5	4	8	7	13	13	20	0	13	3	283	1	0	1	0	7	2	2	9	5	3	7	2	2	18	3	0	3	474
		0.21	3.38	0.42	1.90	1.48	0.00	1.05	0.84	1.69	1.48	2.74	2.74	4.22	0.00	2.74	0.63	59.70	0.21	0.00	0.21	0.00	1.48	0.42	0.42	1.90	1.05	0.63	1.48	0.42	0.42	3.80	0.63	0.00	0.63	100
2	3-4	0	5	0	10	0	0	3	1	11	5	12	6	23	0	7	6	378	0	1	1	2	4	2	0	7	7	3	5	0	3	16	3	3	3	536
		0.00	0.93	0.00	1.87	0.00	0.00	0.56	0.19	2.05	0.93	2.24	1.12	4.29	0.00	1.31	1.12	70.52	0.00	0.19	0.19	0.37	0.75	0.37	0.00	1.31	1.31	0.56	0.93	0.00	0.56	2.99	0.56	0.56	0.56	100
3	6-7	0	0	3	2	4	0	0	2	4	7	2	0	15	0	4	1	309	0	1	0	0	2	2	0	5	13	1	2	0	1	15	2	3	4	406
		0.00	0.00	0.74	0.49	0.99	0.00	0.00	0.49	0.99	1.72	0.49	0.00	3.69	0.00	0.99	0.25	76.11	0.00	0.25	0.00	0.00	0.49	0.49	0.00	1.23	3.20	0.25	0.49	0.00	0.25	3.69	0.49	0.74	0.99	100
4	9-10	0	3	2	4	5	0	1	1	8	9	3	1	18	1	8	0	552	0	0	2	1	4	1	0	7	10	1	2	2	6	24	3	5	4	714
		0.00	0.42	0.28	0.56	0.70	0.00	0.14	0.14	1.12	1.26	0.42	0.14	2.52	0.14	1.12	0.00	77.31	0.00	0.00	0.28	0.14	0.56	0.14	0.00	0.98	1.40	0.14	0.28	0.28	0.84	3.36	0.42	0.70	0.56	100
5	12-13	0	7	1	0	0	0	0	3	2	9	14	4	16	0	6	2	475	0	2	0	4	2	1	0	0	5	5	2	1	4	7	4	3	4	582
		0.00	1.20	0.17	0.00	0.00	0.00	0.00	0.52	0.34	1.55	2.41	0.69	2.75	0.00	1.03	0.34	81.62	0.00	0.34	0.00	0.69	0.34	0.17	0.00	0.00	0.86	0.86	0.34	0.17	0.69	1.20	0.69	0.52	0.69	100
6	15-16	0	6	0	3	0	0	1	0	2	3	5	1	12	0	3	0	362	0	1	0	1	1	0	0	6	3	1	1	0	3	16	2	7	3	445
		0.00	1.35	0.00	0.67	0.00	0.00	0.22	0.00	0.45	0.67	1.12	0.22	2.70	0.00	0.67	0.00	81.35	0.00	0.22	0.00	0.22	0.22	0.00	0.00	1.35	0.67	0.22	0.22	0.00	0.67	3.60	0.45	1.57	0.67	100
7	18-19	0	7	0	0	3	1	5	3	16	0	12	2	25	2	4	2	690	0	1	0	0	2	1	0	9	14	3	3	2	5	13	4	5	2	852
		0.00	0.82	0.00	0.00	0.35	0.12	0.59	0.35	1.88	0.00	1.41	0.23	2.93	0.23	0.47	0.23	80.99	0.00	0.12	0.00	0.00	0.23	0.12	0.00	1.06	1.64	0.35	0.35	0.23	0.59	1.53	0.47	0.59	0.23	100
8	21-22	1	1	0	0	1	1	2	1	1	0	4	0	22	2	2	1	397	0	0	0	0	0	0	0	1	9	2	4	1	1	16	3	9	3	491
		0.20	0.20	0.00	0.00	0.20	0.20	0.41	0.20	0.20	0.00	0.81	0.00	4.48	0.41	0.41	0.20	80.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	1.83	0.41	0.81	0.20	0.20	3.26	0.61	1.83	0.61	100
9	24-25	0	0	0	1	1	1	1	2	4	2	5	0	10	4	5	1	413	0	0	2	0	2	1	0	5	4	1	1	0	4	9	0	5	4	496
		0.00	0.00	0.00	0.20	0.20	0.20	0.20	0.40	0.81	0.40	1.01	0.00	2.02	0.81	1.01	0.20	83.27	0.00	0.00	0.40	0.00	0.40	0.20	0.00	1.01	0.81	0.20	0.20	0.00	0.81	1.81	0.00	1.01	0.81	100
10	27-28	0	2	0	0	1	6	0	1	6	9	9	0	25	2	6	3	599	0	0	1	0	1	2	0	3	7	3	5	0	8	28	4	11	4	749
		0.00	0.27	0.00	0.00	0.13	0.80	0.00	0.13	0.80	1.20	1.20	0.00	3.34	0.27	0.80	0.40	79.97	0.00	0.00	0.13	0.00	0.13	0.27	0.00	0.40	0.93	0.40	0.67	0.00	1.07	3.74	0.53	1.47	0.53	100
11	30-31	0	7	0	4	3	0	0	1	5	2	2	1	14	3	1	3	362	0	0	0	0	1	2	0	2	3	1	3	0	4	22	0	13	3	468
		0.00	1.50	0.00	0.85	0.64	0.00	0.00	0.21	1.07	0.43	0.43	0.21	2.99	0.64	0.21	0.64	77.35	0.00	0.00	0.00	0.00	0.21	0.43	0.00	0.43	0.64	0.21	0.64	0.00	0.85	4.70	0.00	2.78	0.64	100
12	33-34	1	1	2	0	0	0	1	1	4	4	2	0	20	3	4	3	432	0	0	0	0	5	4	1	6	7	2	3	1	7	16	5	9	3	551
		0.18	0.18	0.36	0.00	0.00	0.00	0.18	0.18	0.73	0.73	0.36	0.00	3.63	0.54	0.73	0.54	78.40	0.00	0.00	0.00	0.00	0.91	0.73	0.18	1.09	1.27	0.36	0.54	0.18	1.27	2.90	0.91	1.63	0.54	100
13	36-37	0	8	0	2	0	0	2	2	6	5	3	2	7	1	2	2	360	0	0	0	0	0	2	0	3	4	2	0	1	6	10	7	4	4	445
		0.00	1.80	0.00	0.45	0.00	0.00	0.45	0.45	1.35	1.12	0.67	0.45	1.57	0.22	0.45	0.45	80.90	0.00	0.00	0.00	0.00	0.00	0.45	0.00	0.67	0.90	0.45	0.00	0.22	1.35	2.25	1.57	0.90	0.90	100
14	37-38	0	4	0	0	1	0	1	0	1	3	2	2	6	3	0	1	308	0	6	2	0	3	1	0	9	6	1	4	0	3	9	1	6	3	381
		0.00	1.05	0.00	0.00	0.26	0.00	0.26	0.00	0.26	0.79	0.52	0.52	1.57	0.79	0.00	0.26	80.84	0.00	1.57	0.52	0.00	0.79	0.26	0.00	2.36	1.57	0.26	1.05	0.00	0.79	2.36	0.26	1.57	0.79	100

Table 5c: Core LT-98-18M (pollen counts and percentages for the taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	*Alchornea*	*Amaran/Chen*	*Isoberlinia*	*Artemisia*	*Brchystegia*	*Commiphora*	*Celtis*	*Combretaceae*	*Commelina*	*Cyperaceae*	*Ericaceae (Phillipia)*	*Euphobiaceae*	*Gramineae*	*Holoptelea grandis*	*Moraceae*	*Oleaceae*	*Other Compositae*	*Podocarpus*	*Polypodium*	*Rosaceae*	*Schrebera*	*Typha*	*Verbenaceae*	Trilete Pteridophytes	Monolete Fern Spore	Hidden/Crumpled	Unknown Pollen Taxa	Total counts*/%
1	0-1	0	4	0	4	5	0	5	0	0	16	2	15	186	2	3	19	10	8	14	3	0	2	0	30	6	6	18	369
			1.08		1.08	1.36	0.00	1.36	0.00	0.00	4.34	0.54	4.07	50.41	0.54	0.81	5.15	2.71	2.17	3.79	0.81	0.00	0.54	0.00	8.13	1.63	1.63	4.88	100%
2	3-4	0	2	0	2	7	0	3	1	0	12	1	9	228	0	4	16	6	5	16	3	0	2	0	13	0	9	26	372
			1.08		0.54	1.88	0.00	0.81	0.27	0.00	3.23	0.27	2.42	61.29	0.00	1.08	4.30	1.61	1.34	4.30	0.81	0.00	0.54	0.00	3.49	0.00	2.42	6.99	100
3	6-7	1	2	0	1	1	0	5	2	0	26	0	9	254	2	4	17	11	3	15	1	0	4	0	22	2	5	20	423
		0.24	0.54		0.24	0.24	0.00	1.18	0.47	0.00	6.15	0.00	2.13	60.05	0.47	0.95	4.02	2.60	0.71	3.55	0.24	0.00	0.95	0.00	5.20	0.47	1.18	4.73	100
4	9-10	5	3	0	0	7	0	4	2	1	33	1	22	391	1	8	11	8	2	11	0	0	3	0	31	0	8	20	584
		0.86	0.71	0.00	0,00	1.20	0.00	0.68	0.34	0.17	5.65	0.17	3.77	66.95	0.17	1.37	1.88	1.37	0.34	1.88	0.00	0.00	0.51	0.00	5.31	0.00	1.37	3.42	100
5	12-13	3	2	0	0	5	1	3	0	0	26	0	2	378	1	0	0	0	3	0	0	0	10	0	12	2	13	2	479
		0.63	0.42	0.00	0.00	1.04	0.17	0.63	0.00	0.00	5.43	0.00	0.42	78.91	0.21	0.00	0.00	0.00	0.63	0.00	0.00	0.00	2.09	0.00	2.51	0.42	2.71	0.42	100
6	15-16	2	1	0	0	3	0	1	0	0	8	0	3	263	1	0	4	4	1	6	0	0	8	0	10	1	8	4	340
		0.59	0.29	0.00	0.00	0.88	1.47	0.29	0.00	0.00	2.35	0.00	0.88	77.35	0.29	0.00	1.18	1.18	0.29	1.76	0.00	0.00	2.35	0.00	2.94	0.29	2.35	1.18	100
7	18-19	1	2	1	0	3	2	0	1	3	36	0	5	405	1	0	0	0	1	3	0	0	6	0	6	3	12	3	511
		0.20	0.39	0.20	0.00	0.59	0.39	0.00	0.20	0.59	7.05	0.00	0.98	79.26	0.20	0.00	0.00	0.00	0.20	0.59	0.00	0.00	1.17	0.00	1.17	0.59	2.35	0.59	100
8	21-22	1	1	1	0	2	5	0	0	4	20	0	4	439	0	0	5	5	0	1	0	2	5	0	8	2	7	5	528
		0.19	0.19	0.19	0.00	0.38	0.95	0.00	0.00	0.76	3.79	0.00	1.01	83.14	0.00	0.00	0.95	0.95	0.00	0.19	0.00	0.38	0.95	0.00	1.52	0.38	1.33	0.95	100
9	24-25	2	0	1	0	2	5	0	1	0	27	0	2	324	0	3	1	1	1	3	0	1	6	0	6	2	5	4	405
		0.49	0.00	0.25	0.00	0.49	1.23	0.00	0.25	0.00	6.67	0.00	0.49	80.00	0.00	0.29	0.25	0.25	0.25	0.74	0.00	0.25	1.48	0.00	1.48	0.49	1.23	0.99	100
10	27-28	5	0	0	0	13	13	1	5	4	46	1	3	818	2	1	14	14	3	5	2	0	10	2	10	3	11	4	1018
		0.49	0.00	0.00	0.00	1.28	1.28	0.12	0.49	0.39	4.52	0.10	0.29	80.35	0.20	0.12	1.38	1.38	0.29	0.49	0.20	0.00	0.98	0.20	0.98	0.29	1.08	0.39	100
11	29-30	0	1	1	0	5	12	0	4	1	40	0	1	622	0	1	3	3	1	1	0	1	13	0	23	9	13	4	807
		0.00	0.12	0.12	0.00	0.62	1.49	0.00	0.50	0.12	4.96	0.00	0.12	77.08	0.00	0.12	0.37	0.37	0.12	0.12	0.00	0.12	1.61	0.00	2.85	1.12	1.61	0.50	100
12	30-31	3	4	2	0	9	13	0	3	0	63	0	0	682	0	0	7	4	2	6	0	0	18	0	15	10	9	5	899
		0.33	0.44	0.22	0.00	1.00	1.45	0.00	0.33	0.00	7.01	0.00	0.00	75.86	0.00	0.00	0.78	0.95	0.22	0.67	0.00	0.00	2.00	0.00	1.67	1.11	1.00	0.56	100
13	33-34	4	3	1	0	7	11	0	5	0	69	0	3	833	3	0	11	5	1	7	0	2	20	0	14	7	11	8	1065
		0.38	0.28	0.09	0.00	0.66	1.03	0.00	0.47	0.00	6.48	0.00	0.28	78.22	0.28	0.00	1.03	0.98	0.09	0.66	0.00	0.19	1.88	0.00	1.31	0.66	1.03	0.75	100
14	39-40	0	1	6	1	16	12	12	4	0	59	0	6	948	1	0	9	1	1	10	1	1	22	1	19	4	22	18	1206
		0.00	0.08	0.50	0.08	1.33	1.00	1.00	0.33	0.00	4.89	0.00	0.50	78.61	0.08	0.00	0.75	0.08	0.08	0.83	0.08	0.08	1.82	0.08	1.58	0.33	1.82	1.49	100

Table 5d: Core LT-98-58M (pollen counts and percentages for the taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	Acacia	*Acalypha*	Acanthaceae	*Alchornea*	*Amaran/Chen*	*Brachystegia*	*Bignoniaceae*	*Celtis*	*Commiphora*	*Combretaceae/ Melast.*	*Cyperaceae*	*Phillipia*	*Euphorbiaceae*	*Geraniaceae*	*Gramineae*	*Labiatae*	*Macaranga*	*Moraceae*	*Myrtaceae*	*Cichoriae*	*Palmae*	*Other Compositae*	*Podocarpus*	*Polypodium*	*Proteaceae*	*Cathium*	*Rosaceae*	*Typha*	*Uapaca*	Trilete Pteridophytes	Monolete Fern Spore	Hidden/Crumpled	Unknown Pollen Taxa	Total counts*/%
1	0-1	1	1	1	0	0	2	0	1	0	0	0	1	0	0	82	0	0	0	0	0	0	6	3	9	1	2	1	1	1	17	35	0	1	164
		0.61	0.61	0.61	0.00	0.00	1.22	0.00	0.61	0.00	0.00	0.00	0.61	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	3.66	1.83	5.49	0.61	1.22	0.61	0.61	0.61	10.37	21.34	0.00	0.61	100
2	3-4	1	0	1	0	0	2	0	0	0	0	2	0	7	0	110	0	0	0	0	1	0	5	0	8	0	0	0	1	0	22	0	5	1	173
		0.58	0.00	0.58	0.00	0.00	1.16	0.00	0.00	0.00	0.00	1.16	0.00	4.05	0.00	63.58	0.00	0.00	0.00	0.00	0.58	0.00	2.89	0.00	4.62	0.00	0.00	0.00	0.58	0.00	12.72	0.00	2.89	0.58	100
3	6-7	2	0	0	1	1	2	1	3	1	0	8	0	3	1	227	1	0	2	1	2	1	3	4	5	3	2	1	1	2	28	0	1	1	322
		0.62	0.00	0.00	0.31	0.31	0.62	0.31	0.93	0.31	0.00	2.48	0.00	0.93	0.31	70.50	0.31	0.00	0.62	0.31	0.62	0.31	0.93	1.24	1.55	0.93	0.62	0.31	0.31	0.62	8.70	0.00	0.31	0.31	100
4	9-10	0	4	2	2	1	1	2	3	0	4	14	0	4	0	354	1	6	4	1	0	2	14	3	5	2	0	2	0	2	31	0	2	2	471
		0.00	0.85	0.42	0.42	0.21	0.21	0.42	0.64	0.00	0.85	2.97	0.00	0.85	0.00	75.16	0.21	1.27	0.85	0.21	0.00	0.42	2.97	0.64	1.06	0.42	0.00	0.42	0.00	0.42	6.58	0.00	0.42	0.42	100
5	12-13	1	1	0	0	0	1	4	2	3	0	17	0	3	0	254	0	3	0	0	1	0	9	0	7	0	0	0	1	1	21	3	2	3	365
		0.27	0.27	0.00	0.00	0.00	0.27	1.10	0.55	0.82	0.00	4.66	0.00	0.82	0.00	69.59	0.00	0.82	0.00	0.00	0.27	0.00	2.47	0.00	1.92	0.00	0.00	0.00	0.27	0.27	5.75	0.82	0.55	0.82	100
6	15-16	0	1	1	0	1	1	3	4	3	2	27	1	1	1	288	1	1	2	1	0	0	9	2	4	0	0	0	1	0	21	4	3	3	403
		0.00	0.25	0.25	0.00	0.25	0.25	0.74	0.99	0.74	0.50	6.70	0.25	0.25	0.25	71.46	0.25	0.25	0.50	0.25	0.00	0.00	2.23	0.50	0.99	0.00	0.00	0.00	0.25	0.00	5.21	0.99	0.74	0.74	100
7	18-19	0	1	1	1	1	0	1	0	1	4	17	0	0	1	293	0	0	0	1	1	1	11	1	6	1	0	0	3	1	15	4	0	3	380
		0.00	0.26	0.26	0.26	0.26	0.00	0.26	0.00	0.26	1.05	4.47	0.00	0.00	0.26	77.11	0.00	0.00	0.00	0.26	0.26	0.26	2.89	0.26	1.58	0.26	0.00	0.00	0.79	0.26	3.95	1.05	0.00	0.79	100
8	21-22	0	2	4	0	0	0	0	5	1	5	11	1	4	1	270	1	0	1	0	4	0	9	1	5	0	1	0	1	1	8	2	0	4	336
		0.00	0.60	1.19	0.00	0.00	0.00	0.00	1.49	0.30	1.49	3.27	0.30	1.19	0.30	80.36	0.30	0.00	0.30	0.00	1.19	0.00	2.68	0.30	1.49	0.00	0.30	0.00	0.30	0.30	2.38	0.60	0.00	1.19	100
9	24-25	0	1	4	2	0	2	0	5	9	5	18	0	2	0	477	1	2	0	1	5	1	19	1	4	1	1	0	1	3	26	5	3	8	599
		0.00	0.17	0.67	0.33	0.00	0.33	0.00	0.83	1.50	0.83	3.01	0.00	0.33	0.00	79.63	0.17	0.33	0.00	0.17	0.83	0.17	3.17	0.17	0.67	0.17	0.17	0.00	0.17	0.50	4.34	0.83	0.50	1.34	100
10	27-28	0	0	1	0	0	0	0	3	0	0	6	1	3	0	261	0	1	0	0	2	0	11	0	1	1	1	0	1	1	17	1	2	8	313
		0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.96	0.00	0.00	1.92	0.32	0.96	0.00	83.39	0.00	0.32	0.00	0.00	0.64	0.00	3.51	0.00	0.32	0.32	0.32	0.00	0.32	0.32	5.43	0.32	0.64	2.56	100
11	30-31	0	4	0	2	0	2	1	3	0	5	9	0	0	3	293	0	0	1	0	2	0	11	0	2	0	0	0	0	0	19	1	4	7	365
		0.00	1.10	0.00	0.55	0.00	0.55	0.27	0.82	0.00	1.37	2.47	0.00	0.00	0.82	80.27	0.00	0.00	0.27	0.00	0.55	0.00	3.01	0.00	0.55	0.00	0.00	0.00	0.00	0.00	5.21	0.27	1.10	1.92	100
12	33-34	0	0	2	3	1	0	0	0	0	1	15	0	0	0	263	0	0	3	0	2	0	4	1	10	0	0	0	0	0	18	12	0	4	341
		0.00	0.00	0.59	0.88	0.29	0.00	0.00	0.00	0.00	0.29	4.40	0.00	0.00	0.00	77.13	0.00	0.00	0.88	0.00	0.59	0.00	1.17	0.29	2.93	0.00	0.00	0.00	0.00	0.00	5.28	3.52	0.00	1.17	100
13	36-37	0	1	4	4	0	1	1	1	0	1	7	0	1	1	301	0	1	0	0	1	0	9	1	9	0	0	0	0	0	10	5	2	4	363
		0.00	0.28	1.10	1.10	0.00	0.28	0.28	0.28	0.00	0.28	1.93	0.00	0.28	0.28	82.92	0.00	0.28	0.00	0.00	0.28	0.00	2.48	0.28	2.48	0.00	0.00	0.00	0.00	0.00	2.75	1.38	0.55	1.10	100
14	37-38	0	1	1	4	1	0	0	2	1	2	17	1	2	2	273	0	5	1	0	1	0	13	1	2	0	0	0	2	0	25	10	2	5	380
		0.00	0.26	0.26	1.05	0.26	0.00	0.00	0.53	0.26	0.53	4.47	0.26	0.53	0.53	71.84	0.00	1.32	0.26	0.00	0.26	0.00	3.42	0.26	0.53	0.00	0.00	0.00	0.53	0.00	6.58	2.63	0.53	1.32	100

5e: Core LT-98-37M (pollen counts and percentages for taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	Acacia	Acalypha	Acanthaceae	*Alchornea*	*Amaran/Chen*	*Brachystegia*	*Boraginaceae*	*Bignoniaceae*	*Celtis*	*Commiphora*	*Combretaceae /Melast.*	*Commewlina*	*Cyperaceae*	*Phillipia*	*Euphorbiaceae*	*Gentianaceae*	*Geraniaceae*	*Gramineae*	*Holoptelea*	*Labiatae*	*Leguminosae*	*Macaranga*	*Mallotus*	*Moraceae*	*Cichoriae*	*Oleaceae*	*Palmae*	*Other Compositae*	*Podocarpus*	*Polypodium*	*Proteaceae*	*Rosaceae*	*Trema*	*Typha*	Trilete Pteridophytes	Monolete Fern Spore	Hidden/Crumpled	Unknown Pollen Taxa	Total counts
1	0-1	0	0	0	2	2	3	0	0	0	0	4	4	11	0	6	0	1	232	0	0	0	0	0	0	3	4	0	17	4	4	0	0	0	1	38	1	1	3	342
		0.00	0.00	0.00	0.58	0.58	0.88	0.00	0.00	0.00	0.00	1.17	1.17	3.22	0.00	1.75	0.00	0.29	67.84	0.00	0.00	0.00	0.00	0.00	0.00	0.88	1.17	0.00	4.97	1.17	1.17	0.00	0.00	0.00	0.29	11.11	0.29	0.29	0.88	100
2	3-4	0	3	0	1	0	0	0	2	1	2	1	0	9	0	0	2	2	230	1	1	2	0	0	1	2	0	0	9	0	0	1	0	0	1	34	8	2	2	332
		0.00	0.90	0.00	0.30	0.00	0.00	0.00	0.60	0.30	0.60	0.30	0.00	2.71	0.00	0.00	0.60	0.60	69.28	0.30	0.30	0.60	0.00	0.00	0.30	0.60	0.00	0.00	2.71	0.00	0.00	0.30	0.00	0.00	0.30	10.24	2.41	0.60	0.60	100
3	6-7	0	0	5	3	1	1	0	2	7	3	6	3	11	1	0	4	1	242	0	0	0	0	3	0	1	2	1	15	2	4	1	0	4	1	15	3	0	8	353
		0.00	0.00	1.42	0.85	0.28	0.28	0.00	0.57	1.98	0.85	1.70	0.85	3.12	0.28	0.00	1.13	0.28	68.56	0.00	0.00	0.00	0.00	0.85	0.00	0.28	0.57	0.28	4.25	0.57	1.13	0.28	0.00	1.13	0.28	4.25	0.85	0.00	2.27	100
4	9-10	0	4	1	4	3	3	0	5	4	0	8	0	11	0	2	0	1	227	1	0	1	3	4	0	0	3	1	13	2	3	2	0	0	1	14	2	0	4	328
		0.00	1.22	0.30	1.22	0.91	0.91	0.00	1.52	1.22	0.00	2.44	0.00	3.35	0.00	0.61	0.00	0.30	69.21	0.30	0.00	0.30	0.91	1.22	0.00	0.00	0.91	0.30	3.96	0.61	0.91	0.61	0.00	0.00	0.30	4.27	0.61	0.00	1.22	100
5	12-13	0	5	0	4	0	4	1	0	13	3	5	11	20	0	6	1	0	353	0	0	0	1	9	2	0	3	0	12	4	3	1	0	1	1	13	6	0	2	497
		0.00	1.01	0.00	0.80	0.00	0.80	0.20	0.00	2.62	0.60	1.01	2.21	4.02	0.00	1.21	0.20	0.00	71.03	0.00	0.00	0.00	0.20	1.81	0.40	0.00	0.60	0.00	2.41	0.80	0.60	0.20	0.00	0.20	0.20	2.62	1.21	0.00	0.40	100
6	15-16	0	8	1	4	1	4	0	0	7	6	1	10	15	1	3	1	1	338	0	0	0	0	0	8	0	8	0	7	2	2	2	0	0	1	23	16	3	3	480
		0.00	1.67	0.21	0.83	0.21	0.83	0.00	0.00	1.46	1.25	0.21	2.08	3.13	0.21	0.63	0.21	0.21	70.42	0.00	0.00	0.00	0.00	0.00	1.67	0.00	1.67	0.00	1.46	0.42	0.42	0.42	0.00	0.00	0.21	4.79	3.33	0.63	0.63	100
7	18-19	0	5	1	4	0	0	1	0	3	4	2	7	21	0	2	1	3	345	1	0	1	0	5	3	0	0	0	16	1	0	0	0	1	0	14	1	0	5	452
		0.00	1.11	0.22	0.88	0.00	0.00	0.22	0.00	0.66	0.88	0.44	1.55	4.65	0.00	0.44	0.22	0.66	76.33	0.22	0.00	0.22	0.00	1.11	0.66	0.00	0.00	0.00	3.54	0.22	0.00	0.00	0.00	0.22	0.00	3.10	0.22	0.00	1.11	100
8	21-22	0	3	1	4	2	0	0	1	1	2	2	14	16	1	2	0	0	301	0	1	0	0	3	2	0	5	0	12	3	4	1	0	2	0	9	2	0	5	398
		0.00	0.75	0.25	1.01	0.50	0.00	0.00	0.25	0.25	0.50	0.50	3.52	4.02	0.25	0.50	0.00	0.00	75.63	0.00	0.25	0.00	0.00	0.75	0.50	0.00	1.26	0.00	3.02	0.75	1.01	0.25	0.00	0.50	0.00	2.26	0.50	0.00	1.26	100
9	24-25	0	7	0	3	2	2	0	4	5	2	2	13	23	0	4	1	2	372	0	1	0	0	3	0	2	5	0	10	2	1	0	0	4	1	11	1	1	4	489
		0.00	1.43	0.00	0.61	0.41	0.41	0.00	0.82	1.02	0.41	0.41	2.66	4.70	0.00	0.82	0.20	0.41	76.07	0.00	0.20	0.00	0.00	0.61	0.00	0.41	1.02	0.00	2.04	0.41	0.20	0.00	0.00	0.82	0.20	2.25	0.20	0.20	0.82	100
10	27-28	0	2	1	1	2	2	0	1	3	0	3	7	14	1	3	0	0	244	0	0	0	0	1	3	2	6	0	15	0	2	3	0	2	0	12	1	0	3	332
		0.00	0.60	0.30	0.30	0.60	0.60	0.00	0.30	0.90	0.00	0.90	2.11	4.22	0.30	0.90	0.00	0.00	73.49	0.00	0.00	0.00	0.00	0.30	0.90	0.60	1.81	0.00	4.52	0.00	0.60	0.90	0.00	0.60	0.00	3.61	0.30	0.00	0.90	100
11	30-31	1	4	2	1	2	0	0	1	6	2	7	18	21	0	3	0	3	344	0	1	0	0	0	1	0	9	0	13	1	6	1	1	1	0	17	3	2	4	473
		0.21	0.85	0.42	0.21	0.42	0.00	0.00	0.21	1.27	0.42	1.48	3.81	4.44	0.00	0.63	0.00	0.63	72.73	0.00	0.21	0.00	0.00	0.00	0.21	0.00	1.90	0.00	2.75	0.21	1.27	0.21	0.21	0.21	0.00	3.59	0.63	0.42	0.85	100
12	33-34	2	4	0	0	2	2	0	0	7	2	3	13	15	0	1	2	1	335	0	0	0	0	1	0	0	3	0	11	2	4	0	0	2	0	21	5	1	3	443
		0.45	0.90	0.00	0.00	0.45	0.45	0.00	0.00	1.58	0.45	0.68	2.93	3.39	0.00	0.23	0.45	0.23	75.62	0.00	0.00	0.00	0.00	0.23	0.00	0.00	0.68	0.00	2.48	0.45	0.90	0.00	0.00	0.45	0.00	4.74	1.13	0.23	0.68	100
13	36-37	0	3	0	0	1	0	0	2	0	0	2	7	14	0	4	0	0	255	0	0	0	0	0	2	1	7	0	7	0	1	0	0	3	0	6	7	2	3	327
		0.00	0.92	0.00	0.00	0.31	0.00	0.00	0.61	0.00	0.00	0.61	2.14	4.28	0.00	1.22	0.00	0.00	77.98	0.00	0.00	0.00	0.00	0.00	0.61	0.31	2.14	0.00	2.14	0.00	0.31	0.00	0.00	0.92	0.00	1.83	2.14	0.61	0.92	100
14	39-40	0	2	2	1	0	0	0	0	5	5	4	5	17	0	4	2	2	419	0	1	0	0	0	0	1	3	0	4	1	3	0	0	0	0	8	3	0	2	491
		0.00	0.41	0.41	0.20	0.00	0.00	0.00	0.00	1.02	1.02	0.81	1.02	3.46	0.00	0.81	0.41	0.41	85.34	0.00	0.20	0.00	0.00	0.00	0.00	0.20	0.61	0.00	0.81	0.20	0.61	0.00	0.00	0.00	0.00	1.63	0.61	0.00	0.41	100
15	42-43	0	4	1	1	2	0	0	1	1	6	4	3	22	4	6	3	1	462	0	1	0	0	0	0	0	9	0	7	1	3	0	0	2	0	18	1	3	2	572
		0.00	0.70	0.17	0.17	0.35	0.00	0.00	0.17	0.17	1.05	0.70	0.52	3.85	0.70	1.05	0.52	0.17	80.77	0.00	0.17	0.00	0.00	0.00	0.00	0.00	1.57	0.00	1.22	0.17	0.52	0.00	0.00	0.35	0.00	3.15	0.17	0.52	0.35	100
16	43-44	1	3	2	2	2	1	0	0	2	0	2	6	16	1	1	0	0	260	0	0	0	0	0	0	1	7	0	5	1	0	1	0	2	1	9	3	0	2	329
		0.30	0.91	0.61	0.61	0.61	0.30	0.00	0.00	0.61	0.00	0.61	1.82	4.86	0.30	0.30	0.00	0.00	79.03	0.00	0.00	0.00	0.00	0.00	0.00	0.30	2.13	0.00	1.52	0.30	0.00	0.30	0.00	0.61	0.30	2.74	0.91	0.00	0.61	100

Table 5f: Core LT-98-98M (pollen counts and percentages for the taxa appear on pollen diagram

(Pollen Taxa --->)

Serial number	Sample depth (cm)	Acacia	Acalypha	*Alchornea*	*Amaran/Chen*	*Celtis*	*Cyperaceae*	*Euphorbiaceae*	*Labiatae*	*Liliaceae*	*Poaceae(Gramineae)*	*Macaranga*	*Myrtaceae*	*Oleaceae*	*Cichoriae*	*Other Compositae*	*Palmae*	*Podocarpus*	*Polypodium*	*Proteaceae*	*Symphonia globulifera*	*Trema orientalis*	*Typha*	Trilete Pteridophytes	Monolete Fern Spore	Hidden/Crumpled	Unknown Pollen Taxa	Total counts*/%
1	0-1	0	0	3	11	3	3	4	0	0	246	0	5	4	4	15	0	9	7	0	0	1	0	59	28	0	2	411
		0.00	0.00	0.73	2.68	0.73	0.73	0.97	0.00	0.00	59.85	0.00	1.22	0.97	0.97	3.65	0.00	2.19	1.70	0.00	0.00	0.24	0.00	14.36	6.81	0.00	0.49	100
2	3-4	1	2	4	8	1	6	4	0	1	333	0	16	5	1	28	0	12	5	1	0	0	0	56	18	0	1	514
		0.19	0.39	0.78	1.56	0.19	1.17	0.78	0.00	0.19	64.79	0.00	3.11	0.97	0.19	5.45	0.00	2.33	0.97	0.19	0.00	0.00	0.00	10.89	3.50	0.00	0.19	100
3	6-7	1	2	0	23	0	8	15	0	0	399	0	26	4	4	48	0	31	7	3	0	0	0	75	10	0	4	688
		0.15	0.29	0.00	3.34	0.00	1.16	2.18	0.00	0.00	57.99	0.00	3.78	0.58	0.58	6.98	0.00	4.51	1.02	0.44	0.00	0.00	0.00	10.90	1.45	0.00	0.58	100
4	9-10	1	1	1	7	2	4	4	1	1	243	1	8	2	6	15	1	5	4	0	0	0	2	26	8	0	1	348
		0.29	0.29	0.29	2.01	0.57	1.15	1.15	0.29	0.29	69.83	0.29	2.30	0.57	1.72	4.31	0.29	1.44	1.15	0.00	0.00	0.00	0.57	7.47	2.30	0.00	0.29	100
5	12-13	0	2	0	11	1	9	10	1	0	301	1	9	4	2	32	0	4	8	0	0	0	2	42	19	2	5	471
		0.00	0.42	0.00	2.34	0.21	1.91	2.12	0.21	0.00	63.91	0.21	1.91	0.85	0.42	6.79	0.00	0.85	1.70	0.00	0.00	0.00	0.42	8.92	4.03	0.42	1.06	100
6	15-16	0	0	1	10	1	3	5	0	0	204	1	5	5	2	13	0	4	2	1	1	2	0	28	14	0	2	309
		0.00	0.00	0.32	3.24	0.32	0.97	1.62	0.00	0.00	66.02	0.32	1.62	1.62	0.65	4.21	0.00	1.29	0.65	0.32	0.32	0.65	0.00	9.06	4.53	0.00	0.65	100
7	18-19	1	0	5	8	0	8	8	1	1	346	0	12	6	2	12	0	14	6	1	1	1	0	30	23	2	2	488
		0.20	0.00	1.02	1.64	0.00	1.64	1.64	0.20	0.20	70.90	0.00	2.46	1.23	0.41	2.46	0.00	2.87	1.23	0.20	0.20	0.20	0.00	6.15	4.71	0.41	0.41	100
8	21-22	0	3	4	8	5	9	9	0	0	403	0	14	6	7	28	0	12	2	0	2	0	0	29	1	1	2	569
		0.00	0.53	0.70	1.41	0.88	1.58	1.58	0.00	0.00	70.83	0.00	2.46	1.05	1.23	4.92	0.00	2.11	0.35	0.00	0.35	0.00	0.00	5.10	0.18	0.18	0.35	100
9	24-25	0	0	3	10	2	21	11	0	0	358	1	28	7	12	47	0	7	5	5	4	0	0	53	2	2	5	609
		0.00	0.00	0.49	1.64	0.33	3.45	1.81	0.00	0.00	58.78	0.16	4.60	1.15	1.97	7.72	0.00	1.15	0.82	0.82	0.66	0.00	0.00	8.70	0.33	0.33	0.82	100
10	27-28	0	1	10	14	1	5	16	2	0	359	0	12	1	4	41	0	13	9	4	9	1	1	44	1	1	3	558
		0.00	0.18	1.79	2.51	0.18	0.90	2.87	0.36	0.00	64.34	0.00	2.15	0.18	0.72	7.35	0.00	2.33	1.61	0.72	1.61	0.18	0.18	7.89	0.18	0.18	0.54	100
11	30-31	0	0	8	16	2	9	7	0	0	306	3	4	3	6	35	0	4	9	0	4	1	1	52	12	0	4	480
		0.00	0.00	1.67	3.33	0.42	1.88	1.46	0.00	0.00	63.75	0.63	0.83	0.63	1.25	7.29	0.00	0.83	1.88	0.00	0.83	0.21	0.21	10.83	2.50	0.00	0.83	100
12	33-34	0	0	9	19	2	11	4	1	0	338	0	6	6	1	20	0	9	5	0	4	1	0	53	8	3	4	517
		0.00	0.00	1.74	3.68	0.39	2.13	0.77	0.19	0.00	65.38	0.00	1.16	1.16	0.19	3.87	0.00	1.74	0.97	0.00	0.77	0.19	0.00	10.25	1.55	0.58	0.77	100
13	36-37	0	2	5	18	2	7	9	0	0	300	1	7	6	5	31	0	9	2	0	5	0	1	28	8	1	3	458
		0.00	0.44	1.09	3.93	0.44	1.53	1.97	0.00	0.00	65.50	0.22	1.53	1.31	1.09	6.77	0.00	1.97	0.44	0.00	1.09	0.00	0.22	6.11	1.75	0.22	0.66	100

Table 5g: Core LT-98-82M (pollen counts and percentages for the taxa appear on pollen diagram)

Pollen Taxa --->

Serial number	Sample depth (cm)	*Acacia*	*Acalypha*	*Alchornea*	*Amaran/Chen*	*Celtis*	*Combretaceae/M elast.*	*Cyperaceae*	*Phillipia*	*Euphorbiaceae*	*Poaceae (Gramineae)*	*Leguminosae*	*Macaranga*	*Mallotus*	*Myrica*	*Myrtaceae*	*Oleaceae*	*Cichoriae*	*Other Compositae*	*Podocarpus*	*Polypodium*	*Proteaceae*	*Rosaceae*	*Rubiaceae*	*Symphonia globulifera*	*Trema orientalis*	*Typha*	Trilete Pteridophytes	Monolete Fern Spore	Hidden/Crumpled	Unknown Pollen Taxa	Total counts*/%
1	0-1	3	15	14	8	13	2	40	5	7	396	0	2	9	6	9	13	6	12	43	2	2	6	4	1	15	15	131	17	6	23	864
		0.35	1.74	1.62	0.93	1.50	0.23	4.63	0.58	0.81	45.83	0.00	0.23	1.04	0.69	1.04	1.50	0.69	1.39	4.98	0.23	0.23	0.69	0.46	0.12	1.74	1.74	15.16	1.97	0.69	2.66	100
2	3-4	1	12	14	4	4	7	2	5	5	173	0	0	9	3	19	5	3	6	19	4	1	2	2	2	1	4	106	19	7	10	484
		0.21	2.48	2.89	0.83	0.83	1.45	0.41	1.03	1.03	35.74	0.00	0.00	1.86	0.62	3.93	1.03	0.62	1.24	3.93	0.83	0.21	0.41	0.41	0.41	0.21	0.83	21.90	3.93	1.45	2.07	100
3	6-7	2	21	43	8	5	2	43	3	10	281	0	0	7	7	20	10	4	21	11	6	2	7	3	3	6	8	74	5	9	17	648
		0.31	3.24	6.64	1.23	0.77	0.31	6.64	0.46	1.54	43.36	0.00	0.00	1.08	1.08	3.09	1.54	0.62	3.24	1.70	0.93	0.31	1.08	0.46	0.46	0.93	1.23	11.42	0.77	1.39	2.62	100
4	9-10	2	10	12	8	8	2	22	4	5	251	7	0	4	1	11	12	4	4	4	8	2	0	0	4	4	3	67	6	2	26	516
		0.39	1.94	2.33	1.55	1.55	0.39	4.26	0.78	0.97	48.64	1.36	0.00	0.78	0.19	2.13	2.33	0.78	0.78	0.78	1.55	0.39	0.00	0.00	0.78	0.78	0.58	12.98	1.16	0.39	5.04	100
5	12-13	2	18	13	6	6	2	21	9	5	272	5	0	2	6	11	5	4	12	15	10	3	0	2	4	5	3	84	19	4	24	568
		0.35	3.17	2.29	1.06	1.06	0.35	3.70	1.58	0.88	47.89	0.88	0.00	0.35	1.06	1.94	0.88	0.70	2.11	2.64	1.76	0.53	0.00	0.35	0.70	0.88	0.53	14.79	3.35	0.70	4.23	100
6	15-16	1	10	30	7	9	4	42	7	16	276	5	0	2	9	14	8	3	14	19	4	3	0	4	1	4	6	81	22	2	23	628
		0.16	1.59	4.78	1.11	1.43	0.64	6.69	1.11	2.55	43.95	0.80	0.00	0.32	1.43	2.23	1.27	0.48	2.23	3.03	0.64	0.48	0.00	0.64	0.16	0.64	0.96	12.90	3.50	0.32	3.66	100
7	18-19	2	10	15	5	5	1	42	9	14	292	2	0	6	5	9	7	2	23	17	2	1	1	1	1	8	19	86	2	2	15	623
		0.32	1.61	2.41	0.80	0.80	0.16	6.74	1.44	2.25	46.87	0.32	0.00	0.96	0.80	1.44	1.12	0.32	3.69	2.73	0.32	0.16	0.16	0.16	0.16	1.28	3.05	13.80	0.32	0.32	2.41	100
8	21-22	1	10	11	5	5	1	37	0	2	202	1	0	0	2	3	7	4	9	3	2	1	0	1	5	0	7	60	7	3	9	396
		0.25	2.53	2.78	1.26	1.26	0.25	9.34	0.00	0.51	51.01	0.25	0.00	0.00	0.51	0.76	1.77	1.01	2.27	0.76	0.51	0.25	0.00	0.25	1.26	0.00	1.77	15.15	1.77	0.76	2.27	100
9	24-25	1	11	21	12	2	2	26	6	7	256	4	0	0	5	4	10	7	24	7	9	0	3	2	6	0	9	90	26	4	9	566
		0.18	1.94	3.71	2.12	0.35	0.35	4.59	1.06	1.24	45.23	0.71	0.00	0.00	0.88	0.71	1.77	1.24	4.24	1.24	1.59	0.00	0.53	0.35	1.06	0.00	1.59	15.90	4.59	0.71	1.59	100
10	27-28	1	3	17	10	7	0	40	4	6	364	2	4	2	3	3	4	4	26	11	2	0	2	1	6	4	2	68	13	2	10	626
		0.16	0.48	2.72	1.60	1.12	0.00	6.39	0.64	0.96	58.15	0.32	0.64	0.32	0.48	0.48	0.64	0.64	4.15	1.76	0.32	0.00	0.32	0.16	0.96	0.64	0.32	10.86	2.08	0.32	1.60	100
11	30-31	0	13	13	8	8	1	51	3	3	338	1	3	5	3	1	9	4	14	9	6	3	2	0	3	1	7	74	7	2	3	593
		0.00	2.19	2.19	1.35	1.35	0.17	8.60	0.51	0.51	57.00	0.17	0.51	0.84	0.51	0.17	1.52	0.67	2.36	1.52	1.01	0.51	0.34	0.00	0.51	0.17	1.18	12.48	1.18	0.34	0.51	100
12	33-34	1	5	12	3	6	2	38	0	4	252	3	5	3	3	1	10	1	12	7	4	1	1	1	8	0	2	40	3	2	1	420
		0.24	1.19	2.86	0.71	1.43	0.48	9.05	0.00	0.95	60.00	0.71	1.19	0.71	0.71	0.24	2.38	0.24	2.86	1.67	0.95	0.24	0.24	0.24	1.90	0.00	0.48	9.52	0.71	0.48	0.24	100
13	36-37	1	4	5	3	4	1	36	5	1	336	5	1	0	2	0	5	2	12	9	5	3	2	1	2	3	6	37	10	3	8	508
		0.20	0.79	0.98	0.59	0.79	0.20	7.09	0.98	0.20	66.14	0.98	0.20	0.00	0.39	0.00	0.98	0.39	2.36	1.77	0.98	0.59	0.39	0.20	0.39	0.59	1.18	7.28	1.97	0.59	1.57	100
14	39-40	0	4	7	3	6	1	47	5	4	445	2	1	6	4	2	12	3	25	9	0	2	4	6	1	2	8	49	5	3	5	670
		0.00	0.60	1.04	0.45	0.90	0.15	7.01	0.75	0.60	66.42	0.30	0.15	0.90	0.60	0.30	1.79	0.45	3.73	1.34	0.00	0.30	0.60	0.90	0.15	0.30	1.19	7.31	0.75	0.45	0.75	100
15	40-41	0		7	5	5	5	27	5	2	356	3	0	7	3	0	6	4	8	11	0	2	4	1	1	1	6	65	5	6	2	553
		0.00	0.00	1.27	0.90	0.90	0.90	4.88	0.90	0.36	64.38	0.54	0.00	1.27	0.54	0.00	1.08	0.72	1.45	1.99	0.00	0.36	0.72	0.18	0.18	0.18	1.08	11.75	0.90	1.08	0.36	100

Table 5g: Core LT-98-82M (pollen counts and percentages for the taxa appear on pollen diagram) CONTINUED

16	42-43	0	2	12	9	1	2	35	1	6	328	0	0	2	1	0	6	0	7	8	3	1	1	1	0	0	3	54	1	3	6	508
		0.00	0.39	2.36	1.77	0.20	0.39	6.89	0.20	1.18	64.57	0.00	0.00	0.39	0.20	0.00	1.18	0.00	1.38	1.57	0.59	0.20	0.20	0.20	0.00	0.00	0.59	10.63	0.20	0.59	1.18	100
17	44-45	0	5	2	11	5	1	47	1	3	382	0	1	3	1	2	5	0	11	9	0	3	0	3	1	0	8	33	3	3	4	559
		0.00	0.89	0.36	1.97	0.89	0.18	8.41	0.18	0.54	68.34	0.00	0.18	0.54	0.18	0.36	0.89	0.00	1.97	1.61	0.00	0.54	0.00	0.54	0.18	0.00	1.43	5.90	0.54	0.54	0.72	100

Appendix 5.2 POLLEN TAXA (Common names in brackets)

Acanthaceae (Acanthus)
Anisotes
Justicia
Amaranthaceae/Chenopodiaceae (Amaranth/Goosefoot)
Amarylidaceae (Amaryllis)
Cf. *Gethyllis*
Anacardiaceae (Cashew)
Lannea
Annonaceae (Custard Apple)
Uvariastrum
Aquifoliacea (Holly)
Ilex mitis
Bignoniaceae (Bignonia)
Markhamia
Boraginaceae (Borage)
Mertensia
Cerinthe
Burseraceae (Frankincense)
Commiphora
Campanulaceae (Bellflower)
Combretaceae/Melastomaceae (Indian Almond/Melastome)
Commelinaceae (Spidewort)
Commelina
Compositae (Sunflower)
Artemisia
Subfamily Cichoriae
Genus: *Crepis*
Other Compositae
Cyperaceae (Sedge)
Ascolepis
Cyperus
Ericaceae (Heath)
Phillipia
Euphorbiaceae (Spurge)
Euphorbiaceae
Euphorbia
Acalypha
Croton type
Macaranga
Mallotus
Uapaca
Gentianaceae (Gentian)
Geraniaceae (Geranium)
Pelargonium
Gramineae (Grass)
Guttiferae (Mangosteen)
Symphonia globulifera
Leguminosae (Bean)
Subfamily Caesalpiniaceae (Caesalpinia)
Brachystegia
Delonix
Isoberlinia
Subfamily Mimosacaceae (Mimosa)
Genus: *Acacia*
Mimosa

Labiatae (Mint)
Cf *Aelanthus*
Hauniastrum
Hoslaundia
Ocimum
Liliaceae (Lily)
Cf *Haemerocallis*
Ornithogalum
Lilium
Malvaceae (Mallow)
Hibiscus type
Melianthaceae (Honey-Bush)
Bersama
Moraceae (Fig)
Ficus
Myricaceae (Bayberry)
Myrica
Myrtaceae (Myrtle)
Eucalyptus type
Syzygium type
Oleaceae (Olive)
Olea cf *capensis*
Jasminum
Schrebera
Palmae (Palm)
Elaeis
Monosulcate palmae
Podocarpaceae (Podocarpus)
Polygonaceae (Smartweed)
Polygonum
Polypodiaceae (Polypody)
Polypodium
Proteaceae (Protea)
Protea
Faurea
Ranunculaceae (Buttercup)
Rosaceae (Rose)
Hagenia abyssinica
Parinari
Rubus
Rubiaceae (Madder)
Canthium
Rutaceae (Rue)
Salicaceae (Willow)
Salix
Sapindaceae (Soapberry)
Allophylus
Sterculiaceae (Cacao)
Dombeya
Typhaceae (cattail)
Typha
Ulmaceae (Elm)
Alchornea
Celtis
Holoptelea grandis
Trema orientalis
Verbenaceae (Verbena)
Premna

APPENDIX 6.

Stable isotope data from LT98 core ostracodes

CORE	cm	*species*	_13C (KIS)	±	_18O (KIS)	±	_13C (VPDB)	_18O (VPDB)	Max P
2	6-7	*Rome sp 13*	-3.13	0.01	7.03	0.02	**-6.93**	**2.49**	309
2	9-10	*Rome sp 13*	-3.16	0.01	6.92	0.03	**-6.96**	**2.38**	420
2	12-13	*Rome sp 13*	-3.06	0.01	7.02	0.03	**-6.99**	**2.35**	302
2	15-16	*Rome sp 13*	-2.59	0.04	7.08	0.01	**-6.51**	**2.41**	333
2	18-19	*Rome sp 13*	-3.52	0.02	7.00	0.03	**-7.46**	**2.34**	471
2	21-22	*Rome sp 13*	-2.62	0.01	6.83	0.02	**-6.42**	**2.29**	303
2	24-25	*Rome sp 13*	-2.19	0.01	6.67	0.02	**-5.98**	**2.13**	300
18	0-1	*Rome sp 13*	-3.54	0.02	6.37	0.01	**-7.47**	**1.70**	373
18	3-4	*Rome sp 13*	-3.85	0.01	6.33	0.02	**-7.65**	**1.78**	505
18	6-7	*Rome sp 13*	-3.77	0.01	6.51	0.02	**-7.58**	**1.96**	422
18	9-10	*Rome sp 13*	-3.64	0.01	6.42	0.02	**-7.57**	**1.74**	286
18	12-13	*Rome sp 13*	-3.94	0.00	6.43	0.01	**-7.75**	**1.89**	334
18	15-16	*Rome sp 13*	-2.88	0.04	6.77	0.03	**-6.81**	**2.10**	321
18	18-19	*Rome sp 13*	-2.77	0.01	6.69	0.03	**-6.56**	**2.15**	486
37	43-44	*Rome sp 13*	lost						120
37	43-44	*G. dowingi*	-0.25	0.01	6.60	0.02	**-4.15**	**1.93**	266
37	43-44	*M. opaca*	5.48	0.06	7.24	0.07	**1.75**	**2.71**	210

Notes:

(KIS) is sample measured against internal Univ of Michigan reference

± is one standard deviation on 8 repeated analyses

Max P is the pressure of CO2 generated. 125 is minimum value for correct measurement and represents approximately 10 micrograms of carbonate.