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Holocene Evolution of the Mahakam River Delta Plain, Kalimantan, Indonesia

Introduction

The Mahakam River Delta is located between 0°-2° S Latitude and 116.3°-118° E Longitude, (Fig. 1) and has been the site of a major fluvial depocenter beginning in the middle Miocene (Wain and Berod, 1989). The modern Mahakam River delta has accumulated a 50-70 m thick sea-level high-stand sequence in the past 5000 yrs of the late Holocene eustatic still-stand. The Mahakam River drains approximately 75,000 km^2 of the Island of Borneo and debauches $8xl0^6$ m^3/yr of sediment into the Strait of Makassar. The sediment load is estimated to be 70% silt and clay as suspended load and 30% as coarse to fine sand bed load (Allen and Chambers 1998).

Most well studied deltas, such as the Mississippi River delta, are end members in the ternary classification of Galloway (1975), which relates delta morphology to the relative influence of river input, waves, and tides. The Mahakam River Delta is currently prograding across the narrow Kalimantan shelf under a river dominated regime that is heavily influenced by tidal currents, and very low wave energy. The main effect of the tide seems to be the redistribution of suspended sediment delivered to the delta front across the entire delta plain, and the alteration of distributary hydrology. The Mahakam delta represents a poorly studied realm in deltaic sedimentology and offers an excellent setting to study deltaic deposition under the influence of nearly equal tidal and riverine influences.
Previous sedimentary research in the modern Mahakam delta has focused on active fluvial distributaries (Allen et. al., 1979, Gastaldo et.al., 1995) and on the offshore environments of the delta (Roberts and Sydow, 1996, 2003). The subaerial delta plain of the Mahakam has been subdivided and described in terms of plant taxa and tidal range by Gastaldo and Hue (1993), (Fig. 2), but no in-depth, sedimentary studies of the subaerial and shallow subaqueous delta have been conducted.

This research will utilize an archive of vibracores collected throughout the Mahakam delta plain (Fig. 3). The main goal is to answer a fundamental question. Do proximal/distal gradients in mean grain size and accumulation rates of fine grained sediment exist within the Mahakam delta plain? Also, several of the cores reveal sand bodies below a meter or more of the delta plain mud. Analysis of these sand bodies may lend insight into sand depositional architecture and associated processes in a bifurcating distributary or distributary in process of abandonment

Mahakam River Delta Plain

The subaerial delta plain forms a broad actuate protrusion that extends 40-50 km from the apex of the delta to the coastline comprising several different environments distinguished by vegetation types, salinity and morphology (Allen et al., 1979; Dutrieux et al., 1990). Figure 2 illustrates the major zones, the upper and lower delta plain and distributary systems. At the surface the entire delta plain is considered to exist as a depositionally flat, swampy surface consisting of highly organic carbonaceous mud. While no extensive topographic maps of the plain exist, its surface exhibits a gentle seaward slope, probably on the order of 3 m between the apex and the coastline, a distance of approximately 40-50 km (Allen and Chambers 1998). The entire delta plain is said to be tidal, as the entire surface is inundated at spring high tides. The surface of the delta plain also slopes away from the distributaries with maximum relief of 1 m between distributary banks and interfluves (Allen and Chambers 1998). In spite of this feature, natural levees and crevasse splay deposits are totally absent in the delta plain. This fact distinguishes the Mahakam delta from more fluvially dominated deltas such as the Mississippi (Allen and Chambers 1998). The lack of overbank sedimentation suggests that all sand transport and deposition in the delta plain is restricted to fluvial distributaries, and that tides are the major control on fine grained sedimentation on the delta plain.

The delta plain is incised by two types of channels, fluvial distributary channels and tidal channels. The fluvial distributaries form a diverging network of channels that radiate from the initial bifurcation near Sanga Sanga (Fig. 2). These distributaries are floored by sands from the Mahakam River and are 0.5-1 km in width, and 8-13 m in depth and tend to bifurcate every 10-15 km (Allen and Chambers 1998). They are stable and rectilinear but display a meandering thalweg and channel profiles exhibit the asymmetry seen in meander bends (Gastaldo et al. 1995).

Two major distributary systems are recognized: one that branches to the south and southeast ending in 5 mouths and a second that flows to the northeast and has 4 mouths, only 3 of which are active (Allen et al., 1979). This fact seems to indicate that the northeastern distributary system is waning and eventually all of the northeastern mouths will be abandoned in favor of the southern and southeastern distributary systems (Allen and Chambers, 1998). A completely tidally dominated interdistributary zone, which covers approximately 30% of the delta plain, occupies the central sector between the two main distributary systems. Cores from this area have revealed sandy deposits that suggest a distributary system may have been present in this section of the delta (Allen and Chambers 1998).

The tidal channels occur mainly in the lower delta plain and are characterized by high sinuosity in the upper reaches and wide flaring mouths at the distal extremity. These channels are generally unconnected to the fluvial distributary network and as such have no access to fluvial sands. They are floored by mud having a high organic content and may contain isolated sands where a channel has incised through a sandy fluvial deposit (Allen et el., 1979).

Discussion and Proposed Research

It seems evident that deposition of fine sediment on the subaerial delta plain is controlled mainly by tidal currents. I hypothesize that a proximal/distal gradient exists for both modal grain size and accumulation rates of this fine sediment, due to proximal/distal differences in the tidal influence on the delta plain. Both parameters are expected to increase with distance from the apex of the delta plain. It is further hypothesized that gradients may also exist between the two major distributary zones, and interdistributary zone, which are believed to be under different magnitudes of tidal influence (Allen and Chambers 1998). Grain size analysis of delta plain mud from all cores will answer the question of proximal/distal gradient. Also, the mud will be characterized in terms of total organic carbon and carbonate content.

Although the subaerial delta plain is characterized by organic, carbonaceous mud at the surface, 10 of the 53 cores collected from the delta plain contain significant, (.5-2m thick) sand bodies. If it is true that all sand transport and deposition is constrained to the fluvial distributaries, then these deposits are records of the last significant sand deposition within a fluvial distributary. Allen and Cahmbers (1998), have suggested that as the delta plain has grown, distributary mouth bars have become stranded as fluves bifurcated around them and continued to prograde, stranding the bar within the delta plain. Also possible is the abandonment and fill of a fluvial channel. Analysis of the cores will provide insight into the processes that formed and stranded these sands within the delta plain.

Materials

Sample collection and Processing

A total of 53 vibracores were collected by VICO personnel in 1994 from several environments within the subaerial delta plain, including hardwood, Nypa palm and mangrove swamp, distal delta headlands, tidal channels, interdistributary areas, and inactive channel bars. These cores were transported to Coastal Studies Institute core lab at Louisiana State University where they were prepared for X-ray radiography. The process involved cutting the 7.5 cm diameter aluminum core barrel into 25 cm sections and splitting it longitudinally. One half was archived and the other half placed in a specially built slabbing frame and sliced to a 1 cm thick slab which was wrapped in plastic and then radiographed. Radiographs were prepared using a Norelco 150kv constant potential beryllium window X-ray tube. Slabs were exposed for 2-3 minutes at 28kv, 20ma, 21.5cm focal spot and 38 cm film to X-ray source distance. Samples were exposed on to Kodak Redi Pak Type M industrial film.

Before storage, the half core to be archived was subsampled at approximately 50cm intervals, stored in sealed glass containers and refrigerated for a variety of future analysis. All remaining material was labeled and stored at the Basin Research Institute Core Repository at LSU.

Methods Granulometry, Total Organic Gabon, and Carbonate content

Grain size, TOC, and carbonate content analysis of the delta plain mud will be conducted on the refrigerated subsamples. These samples have experienced the least desiccation and oxidation and given their storage, should yield valid results. Carbonate and TOC content analysis will utilize the loss on ignition method in a muffle furnace. Grain size analysis will be preformed on a Micromer-tics Sedigraph. Approximately 500 delta plain mud samples are in queue for analysis. Grain size analysis of the sand bodies will be conducted on archived core sections used to produce the X-radiographs. Analysis will be performed on a Gilson Gilsonic Ultra Siever Model GI-A. Samples are first passed through a 63 micron sieve to determine sand to mud ratio. The coarse fraction is then sonic sieved at quarter phi intervals ranging from 0-5.25 phi. Calculation of mean grain size and sorting values are preformed using the methods prescribed by Inman (1952). Approximately 650 samples are in queue to be analyzed.

Radio nuclides

Radioisotopic analysis of the fine grained deposits will be performed. The nuclides of interest are Pb-210, a naturally occurring radioactive tracer and Cs-137, an anthropogenicaly introduced isotope, useful as an absolute time marker in the sediment column. This analysis provides information on either rate of accumulation and/or biologic mixing processes. It is unclear at the present if any cores will be usable for accumulation rates given the interpreted high amounts of bioturbation in these deposits. . The x-radiographs will be used to determine which cores are the least bioturbated and have the best potential for offering accumulation rates. If accumulation rates are not obtainable, then this analysis will lend insight into rates of biologic mixing of the sediments. Phytoclasts contained in the delta plain mud may be examined for C-14 by AMS. This analysis will also help to absolutely date the age of the delta plain.

X-radiographs

The x-radiograph negatives have been converted to digital format at the Coastal Studies Institute. These digital images will be imported to AutoCAD. This powerful program will allow the reconstruction of the individual radiographs into a continuous image representative of the original core. Regular photographs of the core segments will undergo the same treatment. AutoCAD will be used to make precise measurements of the size and geometry of sedimentary structures, both physical and biologic. These measurements will aid in the delineation and comparison of sedimentary facies contained in these cores. The description of both primary and secondary (post-depositional) structures will further add to the interpretation of depositional processes. The final product will be revised core logs that display accurate information about grain size, sedimentary structures and bioturbation in conjunction with core photographs and x-radiographs.

Conclusion

This proposed research will fill several noticeable gaps in the literature and school of thought on sedimentation in the Mahakam River delta plain. The process of tidal redistribution of suspended sediments in terms of proximal/distal gradients and distributary zones will be studied in detail by granulometric and geochemical investigations. The radionuclide investigation should produce accumulation rates for the delta plain mud, and reveal any proximal/distal gradients rates of deposition. Our understanding of the process of channel bifurcation or abandonment will be furthered by the granulometric study of sand bodies found buried beneath the delta plain mud. The Holocene evolution of the Mahakam River delta plain will be better understood as a result of this project. This will further our knowledge of sediment deposition in river dominated, tidally influenced deltas.

Figure 1. Map displaying location of study area.

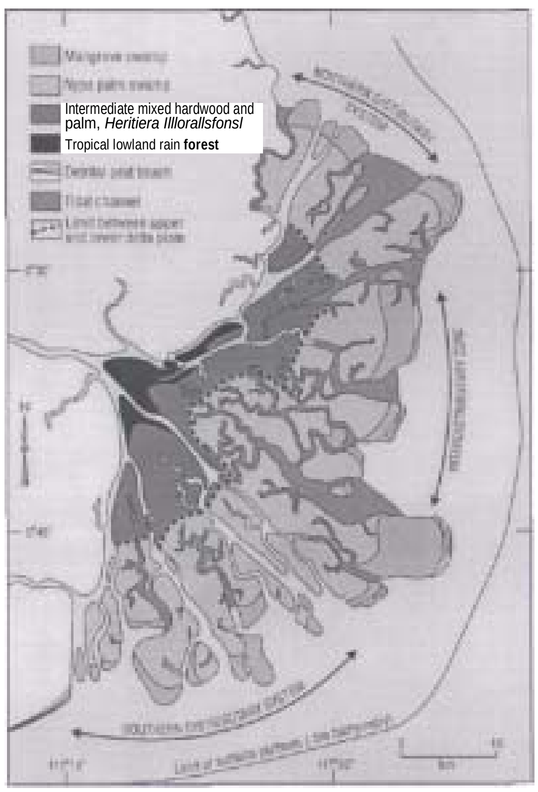

Figure 2. Map displaying major zones of The Mahakam delta plain.

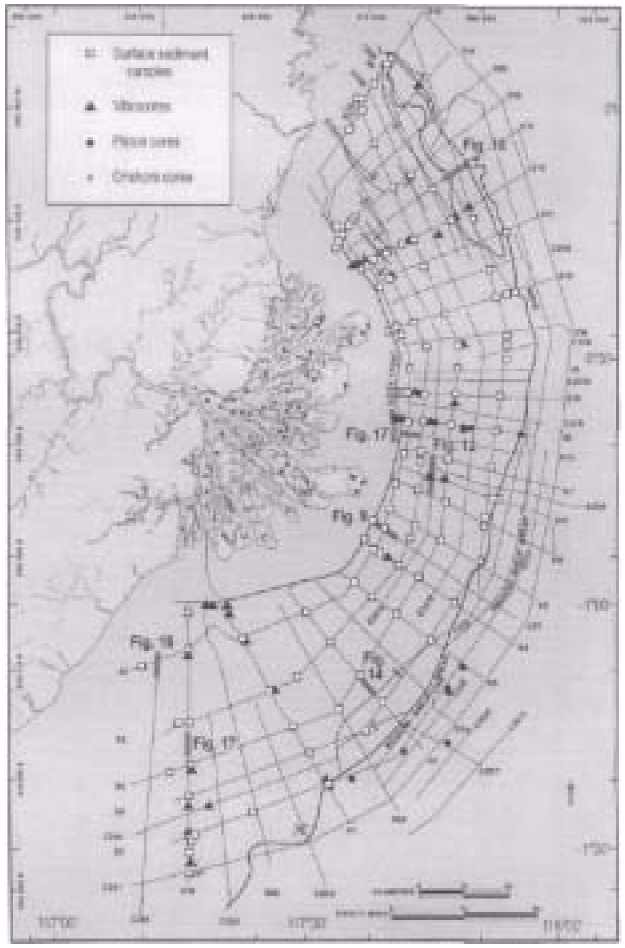

Figure 3. Map displaying the location of onshore Vibracores, denoted by stars.

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Timeline

Work to date Spring 2003
Literature review
Perusal of x-radiographs, photographs, archived cores, and subsamples

Fall 2003
Sub sampling of cores containing sand bodies
Digitization of x-radiographs and photographs of selected cores
Importation of digital images into AutoCAD
Grain size analysis of 150 sand samples

Anticipated timeline for project completion
Winter Break 2003-2004
Completion of grain size, toe and carbonate content for delta plain mud.

Spring 2004
Completion of grain size analysis for delta plain sand bodies.
Reduction and synthesis of all data

Summer 2004
Completion of radioisotope analysis Complete data
synthesis Writing thesis

Fall 2004 Complete thesis
Complete course work
Defend thesis