

The Dynamics of Mahakam Delta - Indonesia, Based on Spatial and Temporal Variations of Grab Samples, Cores, and Salinity*

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Abstract

During years 2005-2009, observations on modern sediment of Mahakam Delta in the southern and the northern lobes were conducted using grab samples on the river bed in conjunction with echo sounding, shallow core sampling, and salinity measurements. The delta environments observed were head of passes, upper delta plain, lower delta plain, and delta front. The purpose was to try to develop analogues, as detailed as possible, for the Miocene/Pliocene deltas being explored and exploited in the area.

Decreasing grain size on the river bed from the head of passes to delta front was observed in the northern lobe. Similar pattern, however, was not apparent in the southern lobe, where there was a distinct anomaly of coarser grain size from lower delta plain to delta front area. This indicates by-pass sedimentation or effect of relics of submerged previous lower delta plain sands which are now being transgressed. Most of the thalweg areas in the channels were devoid of sands; instead, grab samples usually found semi-consolidated clay. Active sand transportation and deposition locus were the slopes of the point bars and side bars. Shallow cores in the lower delta plain were generally characterized by clay drapes, both in the northern and the southern lobes, suggesting tidal processes were operational in almost the same intensity in both areas. Salinity measurements in the water and sediments both showed an increasing trend from upstream to downstream, with the northern lobe being more intruded by the seawater profiles. Variations of salinity with times were also observed to be controlled by tidal-activity periods.

The implications of these new observations to the subsurface mapping of the Miocene/Pliocene delta are very interesting ones. Updip shale-out trap of delta front mouth-bar sands maybe worth pursuing, as well as a new model of fluvial sands, in contrast to delta plain sand geometry with respect to clay-plugs and edge-of-channel. Tidal-effect reservoir models may also be revisited in the context of lobe relative positions and formation-water salinity.

Selected References

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The Dynamics of Mahakam Delta Components Based on Spatial and Temporal Variations of Grab Samples, Cores, and Salinity



GDA Consulting

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Andi Krisyuniyanto (2), Purnama A S (2)
(1) *ETTI* , (2) *GDA Consulting*

See notes following

Presenter's Notes:

I present a sedimentological study of a modern delta depositional system based on periodic sampling both in different components of delta morphology; namely, fluvial, delta plain, and delta front areas.

Mahakam Delta is a very famous delta in Indonesia which has been receiving much attention from sedimentology researchers and has been used widely as an analogue for delta depositional model in the region.

The number of co-authors here reflects the complexity of the field study operation and technical challenges that require expert management by good team of researchers.

Content

Introduction

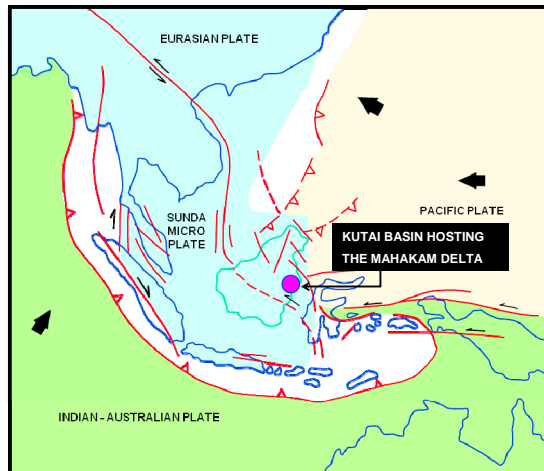
Methods

Results

Conclusions

Presenter's Notes: First, I introduce the Mahakam Delta, both geologically and specifically sedimentologically. Then, I will briefly discuss the methodology that we used in conducting the field sedimentological study. A rather lengthy description of the results will follow. Finally I conclude the presentation with several statements regarding this continuing study

INTRODUCTION



Mahakam Delta is located in the island of Kalimantan (Borneo), Indonesia

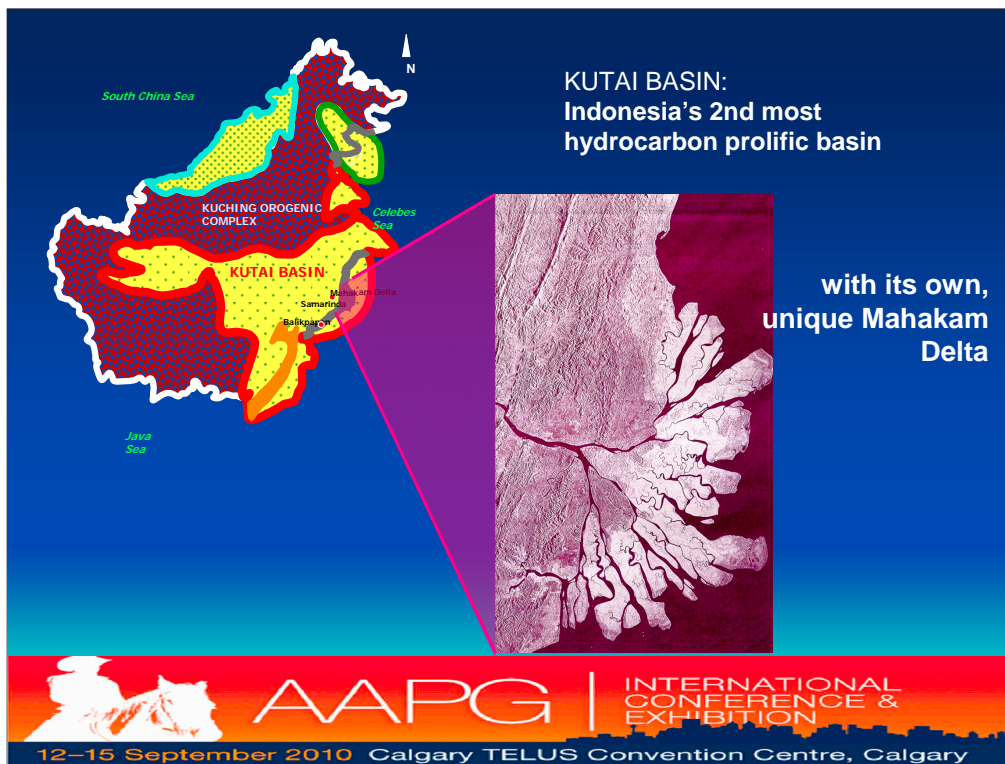
The tectonic setting is in the junction of three (3) major plates (Eurasia – Indian Australian – Pacific)

It is contained in the Kutai Basin of Kalimantan

Presenter's Notes: Mahakam Delta is located in Kalimantan or Borneo, the second largest island in Indonesia.

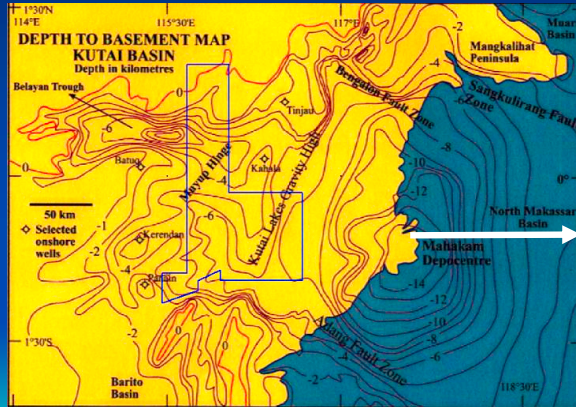
The tectonic setting is at the junction of 3 major plates, Eurasia with Sunda Microplate to the north and northwest, the Indian-Australian plate to the southwest, south and southeast, and the Pacific plate to the east.

The delta is in the Kutai sedimentary Basin.



Presenter's Notes: Kutai Basin is the second most hydrocarbon prolific basin in Indonesia, after the Central Sumatra Basin. It holds at least 11 Billion Barrels of Oil equivalent recoverable reserves, most concentrated in and around the Mahakam Delta area. From its surface morphology it is quite clear that the modern Mahakam Delta is a mixed fluvial-tidal delta.

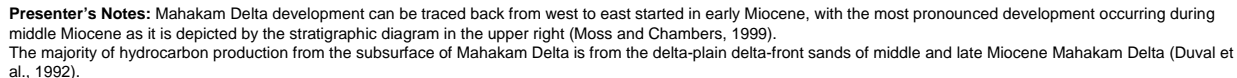
INTRODUCTION



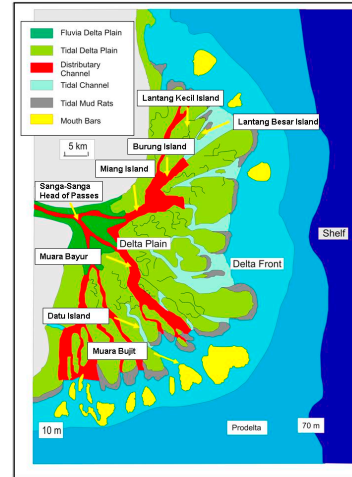
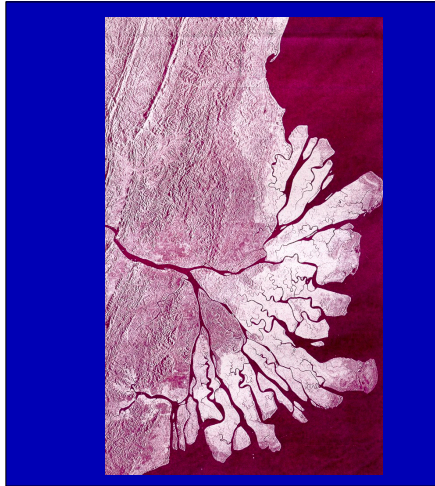
**MAHAKAM DELTA IS
LOCATED ON THE
DEPOCENTER OF KUTAI
BASIN WHICH PILED UP TO
14 KM SEDIMENT ABOVE
TRANSITIONAL /
ACCRETED BASEMENT**

Presenter's Notes: Kutai Basin, which hosts the Mahakam River delta, is a Tertiary Indonesian basin known to have thickest sediment accumulation. A total thickness of 14 km is interpreted at its depocenter. The deepest onshore well drilled in this delta area reached TD of 16,800 feet (+/- 5.1 km), and still in middle Miocene section; it did not reach the Oligocene or syn-rift Eocene section.

Mahakam Delta development can be traced back from early Miocene, with the most pronounced development during middle Miocene. The modern 70-meter delta package was age-dated to be as old as 6 KYA



INTRODUCTION



The Morphology of Mahakam Delta and Sampling Site Position
 (Modified after Allen & Chambers, 1998)

Presenter's Notes:

The surface morphology of Mahakam River and Delta captured by satellite image (left) indicates that the river (and delta) was in existence long before the latest structural development of the onshore area. The river cuts across the structures downstream from Samarinda area.

The satellite image, however, does not suggest the state of lobe activity of the several lobes developed in the delta

The map on the right depicts the development of mouth-bar sands (yellow colored) in front of distributary channels; it becomes apparent that the southern lobes are more active than the northern ones, as indicated by the better development of mouth-bar sands in the south compared to the north

The components of the delta are: dark green is the upper delta plain which is mostly fluvial; light green is the lower delta plain which is more tidally influenced; red is the distributary channel. Very light blue is the delta front which contains the yellow distributary mouth bar sands; the moderate blue is the prodelta.

The deep blue is the shelf area, seaward of prodelta, bounded by 70-meter bathymetric contour.

The yellow arrows and the white flags indicate the locations (7) of sampling for this study, which covers fluvial, upper delta plain, lower delta plain, and delta front areas, both northern lobe and southern lobe.

BACKGROUND

- Observations on modern sediment of Mahakam Delta during years 2005 – 2010
- Since publication of Allen and Chambers' (1998) Mahakam Delta book, no more comprehensive research on Mahakam Delta has been conducted.

OBJECTIVE

- Initial results of a long term sedimentological study of the modern Mahakam Delta
- Provide updated analogues of delta geological model in the subsurface

Presenter's Notes:

This research is based on periodic visits to the delta up to three times a year with 2-3 day from 2005 to 2010, cruising along the delta. Most of the time the visit was in association with field trip programs for geoscientists and students, led by senior author.

The research is needed because the last publication on Mahakam Delta was by the late George Allen and John Chambers in 1998. A research by Sallahudin and Lambiase (2004, 2006) gave some alternative insight into the initial hypothesis as to why the modern mouth bar sands are of better quality than the distributary channels. However, there has not been any follow-up to their work.

The objective of this study is to present the initial results of a long-term sedimentological study of the modern Mahakam Delta and at the same time provide further analogues of delta geological models in the subsurface.

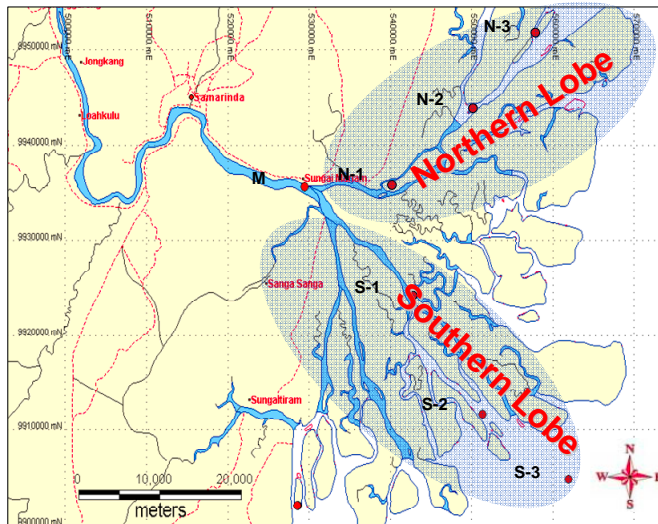


AAPG

INTERNATIONAL CONFERENCE & EXHIBITION

12–15 September 2010 Calgary TELUS Convention Centre, Calgary

LOCATION MAP



Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

See notes following

Presenter's Notes:

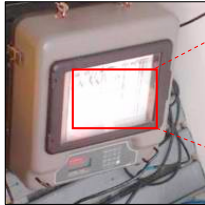
This map shows our observation locations. We divided the area into the northern lobe and southern lobe. Location 1, Mariam River, includes the fluvial rather than the delta. It is slightly upstream of the head of passes.

On the northern lobe are N1 Miang Island in upper delta plain, N2 Burung Island in lower delta plain, and N3 Lantang Island in lower delta plain – delta front area.

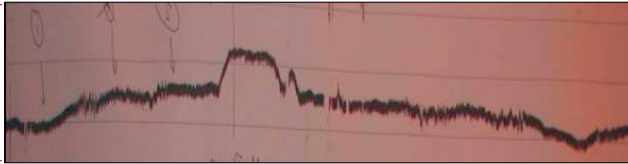
On the southern lobe are S1 Muara Bayur in upper delta plain, S2 Datu Island in lower delta plain, and S3 Muara Bujit in delta-front setting.

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METHODS



Echo Sounding



River Bottom Profile



Grab Samples



Core Sample



Salinity

[See notes following](#)

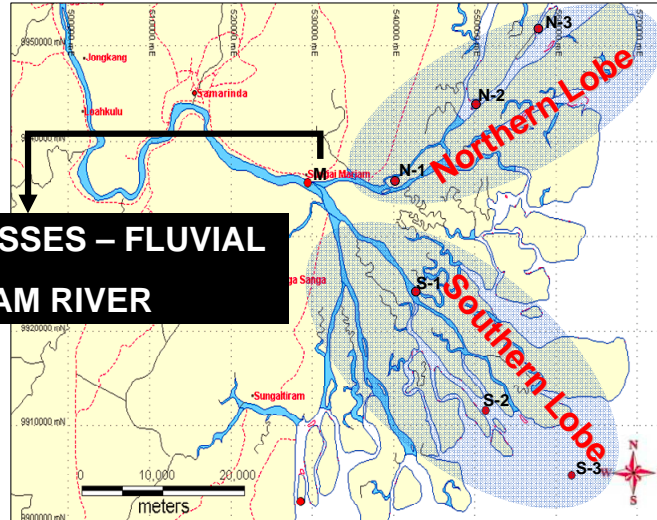
Presenter's Notes:

The methods employed in the survey were :

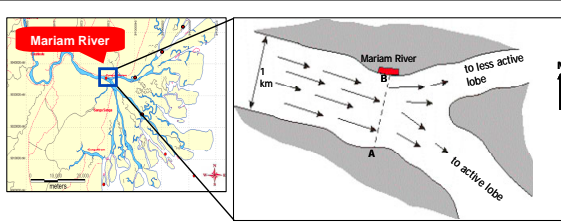
1. Using echo sounder to get river bottom profile from our boat
2. Using grab sampler metal cone with-30 meter chain to grab bottom samples
3. Using PVC core barrel, 4-meters in length, with metal core catcher at the base to get sediment core. The core barrel was pushed into the bottom sediments by using wooden hammer.
4. Measuring salinity of the river water as well as the sediment sampled, by using hand-held portable conductivity meter.
5. Visually describing all the sediments (grab and core) using loupes and microscopes.
6. Analyzing the distribution of grain size by using granulometric method in laboratory.

RESULTS

HEAD OF PASSES – FLUVIAL MARIAM RIVER



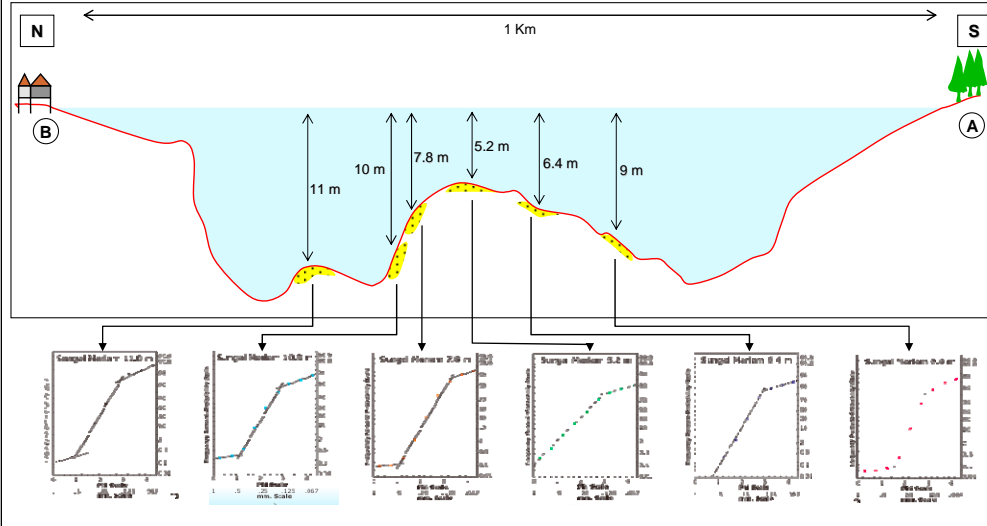
Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit



GRAB SAMPLE AND RIVER PROFILE

Location : Mariam River

Date : 2005



See notes following

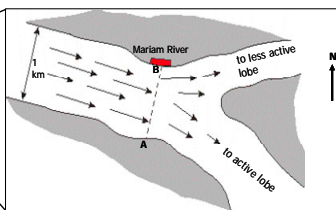
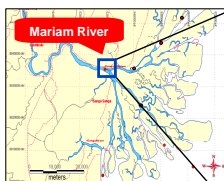
Presenter's Notes:

In 2005, a river bottom profile indicated bifurcation of the thalweg, the northern being the deeper.

A small bump on the northern thalweg was initially thought to be bedform actively migrating both toward the north (following lateral accretion) and toward the east (following overall current direction)

The granulometric data indicate increasing grain size toward the northern thalweg and decreasing grain size, as well as more suspension, away from the river bar crest to the southern shallower thalweg.

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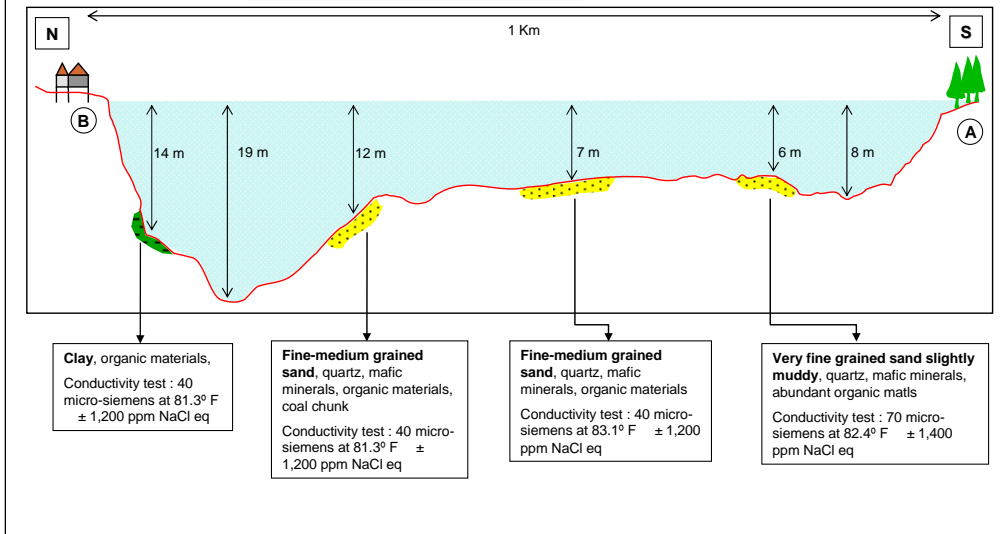
GRAB SAMPLE AND RIVER PROFILE

Location : Mariam River

Date : March 25, 2009

Time : 09.00 – 10.00 AM

Weather : Cloudy



See notes following

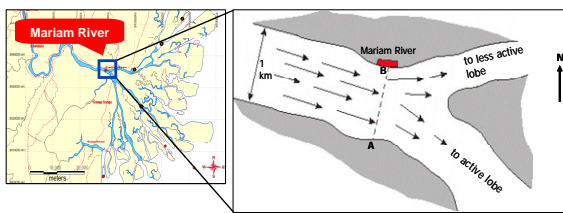
Presenter's Notes:

In 2009, a similar situation in bottom river profile, with the deepest thalweg in the north, which proved to be 19 meters; the grab sample on the edge of northern thalweg resulted in scraping off of semi-consolidated clay.

Again there is increasing grain size toward the northern thalweg, but in this case, at the deepest part of the thalweg, no sediment was being deposited.

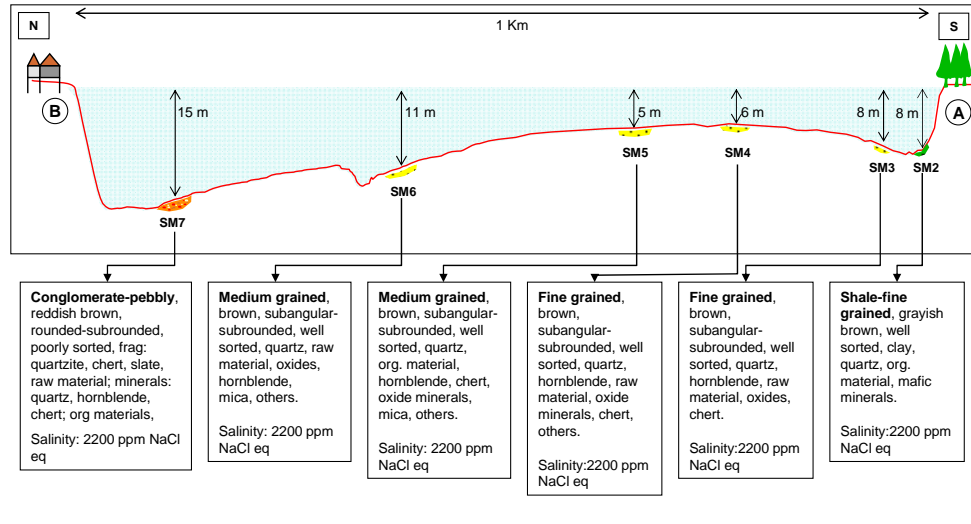
The salinity of water and sediment in this area is 1200 ppm NaCl eq.

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GRAB SAMPLE AND RIVER PROFILE

Location : Mariam River
 Date : 07th Aug 2010
 Time : 08.48 Pm
 Weather : Cloudy



See notes following

Presenter's Notes:

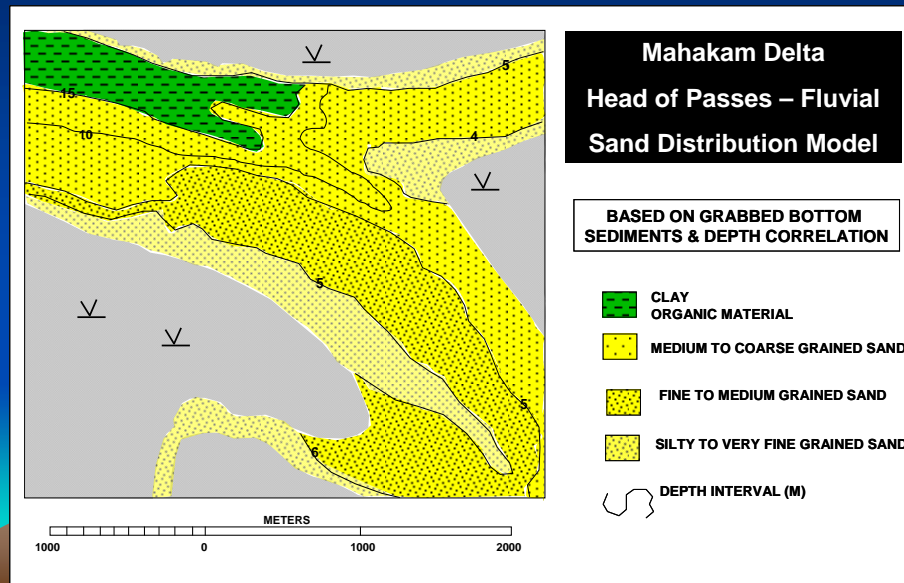
In 2010, we found conglomerate-pebble grain size at a depth of 15 meters, close to the thalweg greatest depth. However, there was absence of sediment at the bottom of the greatest thalweg depth.

The 6-year survey shows that the small undulation close to the thalweg area on the flank of the point bar is not really a sand-wave bedform because it did not move during that time. It might be related to irregularities in the bedrock controlled by structure.

Salinity was measured as increasing, most recently 2200 ppm NaCl equivalent.

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RESULTS

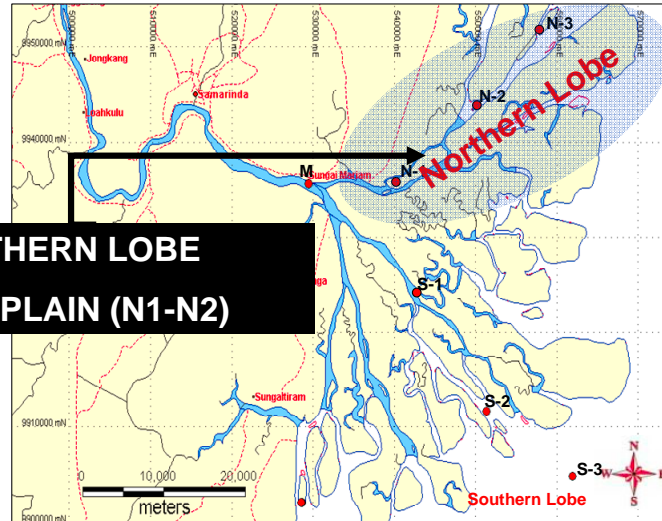


Presenter's Notes: As a result of our periodic sampling and bottom profiling, we made tentative sand distribution model of head of passes fluvial system in Mahakam River-Delta, as depicted on this map. The number indicates the depth, which is deeper than 15 meters in the thalweg, which is composed only of clay.

It is thought that sediments were not deposited in the thalweg area, due to current intensity.

RESULTS

NORTHERN LOBE DELTA PLAIN (N1-N2)



Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

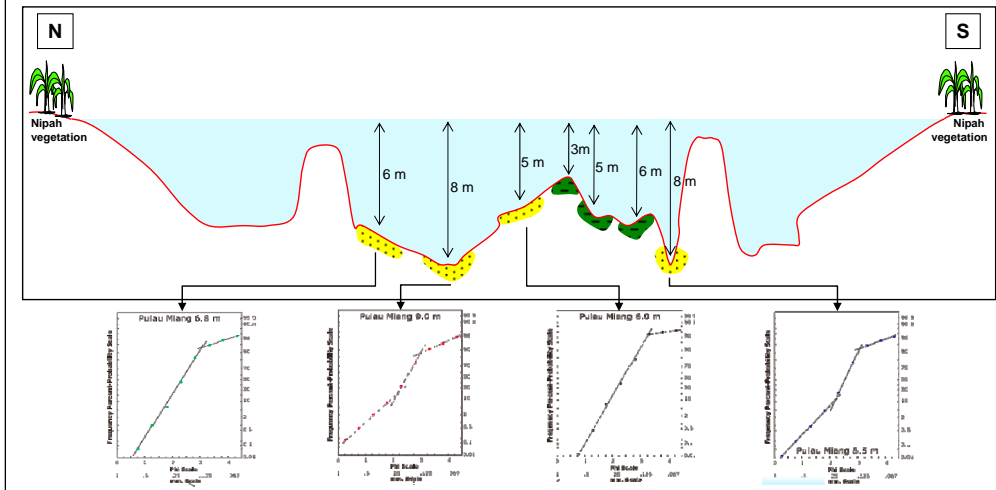
Presenter's Notes: Northern Lobe sampling, especially in the delta-plain area: N1 and N2



GRAB SAMPLE AND RIVER PROFILE

Location : Miang Island

Date : 2005



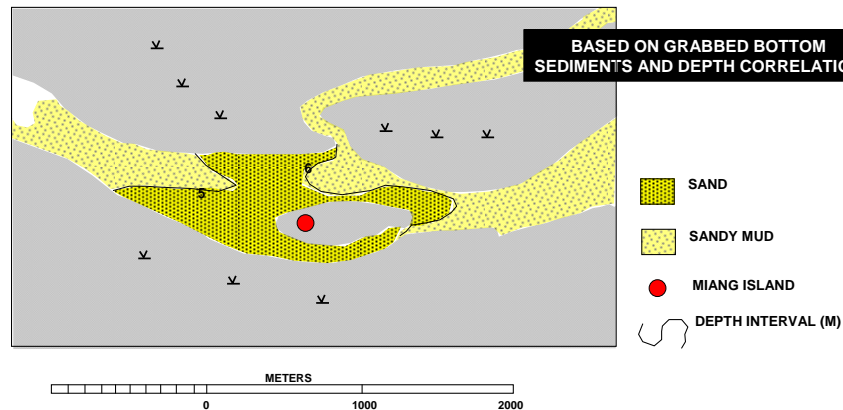
Presenter's Notes: The greatest depth in this upper delta plain distributary channel is 8 meters.

The irregularities of the river bottom might be associated with the abandonment processes of the northern lobe.

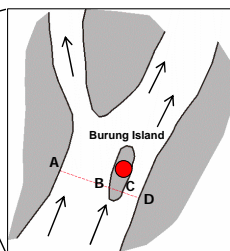
Suspension-laden deposition seems to be dominating the granulometric profile.

On the surface of the mid-channel bar we also found some clay in grab samples, indicating very low energy.

MAHAKAM DELTA INACTIVE LOBE UPPER DELTA PLAIN DISTRIBUTUTARY CHANNEL SAND DISTRIBUTION MODEL (N1 – MIANG ISLAND)

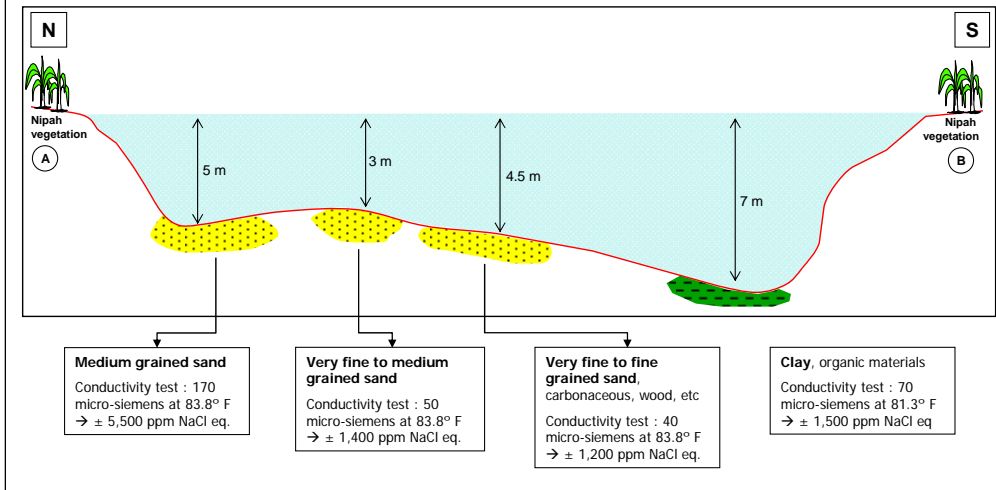


Presenter's Notes: This is the model of sand distribution in the upper delta plain of the northern lobe, which is now in the process of abandonment. The sand usually is concentrated only on mid-channel bar, while in the deeper part, the sand is mixed with some clays, resulting in sandy mud deposition.



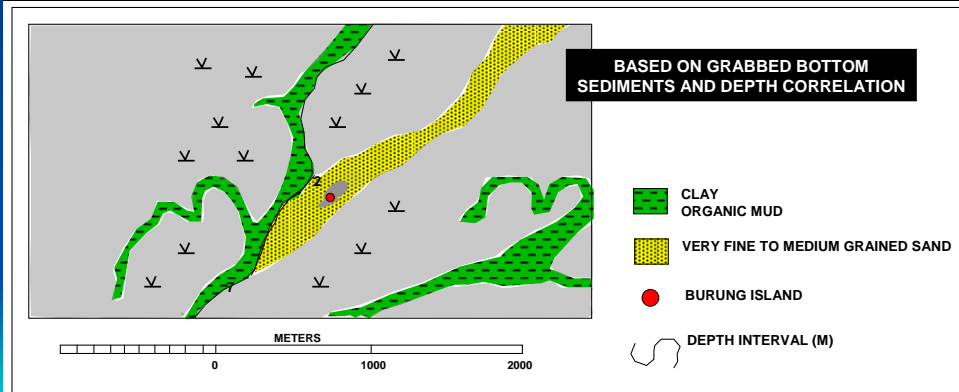
GRAB SAMPLE AND RIVER PROFILE

Location : Burung Island
 Date : March 26, 2009
 Time : 10.00-11.30 PM
 Weather : Bright



Presenter's Notes: Downstream of N1, lower delta plain Burung Island sampling indicates that the deepest thalweg is only 7 meter and is occupied by organic clays. The sands developed in shallower depths represent the remnant of previous active distributary channel. Salinity of water can be up to 5000 ppm NaCl eq at this location.

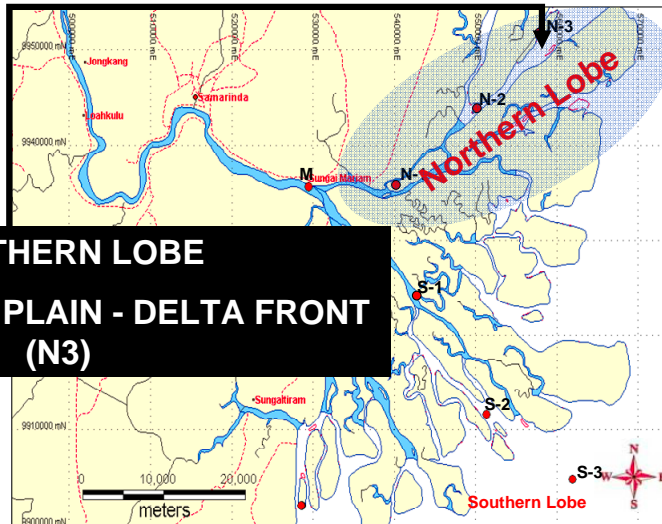
MAHAKAM DELTA INACTIVE LOBE LOWER DELTA PLAIN DISTRIBUTARY CHANNEL SAND DISTRIBUTION MODEL (N2 – BURUNG ISLAND)



Presenter's Notes: The sand distribution model in abandoned lobe, lower delta plain distributary channel (suggested to be N2 Burung Island), indicates that the sand in this area is a remnant of previous active processes of distributary channel; the deep thalweg resulted from the scouring of tidal currents, with clays and organic material deposited during high tide.

RESULTS

NORTHERN LOBE LOWER DELTA PLAIN - DELTA FRONT (N3)

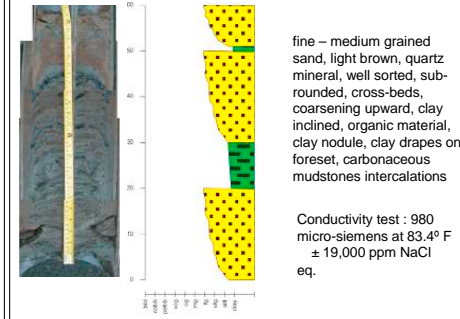
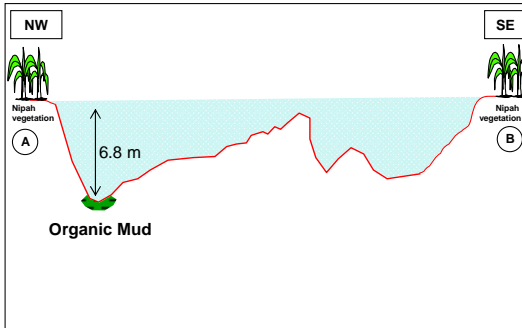


Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

GRAB SAMPLE, RIVER PROFILE, AND CORE SAMPLE



Location : Lantang Island
 Date : March 26, 2009
 Time : 14.00-15.00 PM
 Weather : Cloudy



Presenter's Notes: In this lower delta plain area, the deepest thalweg is 6.8 meters and contains organic mud . The majority of the coring that we have managed to get in the submerged longitudinal bar of Lantang Island. The profile of coarsening upward sequence of fine- to medium-grained sands with abundant clay drapes both within the sand body and especially in the interbedded mud-siltstone. The salinity in this area is quite high, 19000ppm NaCl equivalent.



Striping sand-silt formed because of tidal influence!

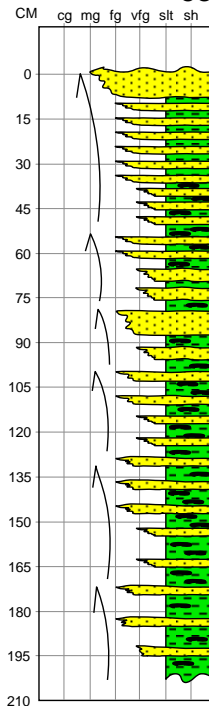
Conductivity test : 4.2 milli-siemens at 85.4° F ± 12000 ppm NaCl eq.



CORE SAMPLE DESCRIPTION

Location : Lantang Island

Date : June 2008



very fine – medium grain sand, gray – light brown, loose, coarsening up, organic material, quartz mineral, interlamination with dark gray clay, carbonaceous.

very fine – fine grain sand, gray – dark gray, coarsening up, organic material, interlamination with dark gray clay, carbonaceous.

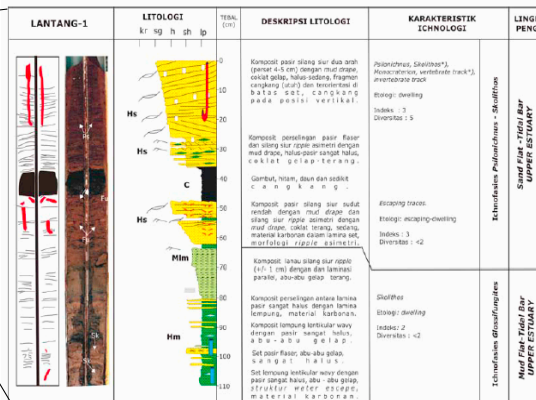
very fine – fine grain sand, dark gray, loose, coarsening up, organic material, interlamination with dark gray clay, carbonaceous.

very fine – fine grain sand, dark gray, coarsening up, organic material, interlamination with dark gray – black clay, carbonaceous.

very fine – fine grain sand, dark gray, coarsening up, organic material abundant, interlamination with black clay and dark gray silt, carbonaceous.

very fine – fine grain sand, dark gray, coarsening up, organic material abundant, interlamination with black clay and dark gray silt, carbonaceous.

Presenter's Notes: At the edge of the side bar, the core shows interbedded – interlaminated sand and silt and mudstone with abundant carbonaceous material in it. These indicate periodical processes of tidal action. Ripples and burrows were also observed as common features in this area.



Profile of *intertidal flat – tidal bar upper estuary* deposit in Lantang

Ichnofauna is not significantly developed, but the varieties occur at surface

Date : 2005



See notes following

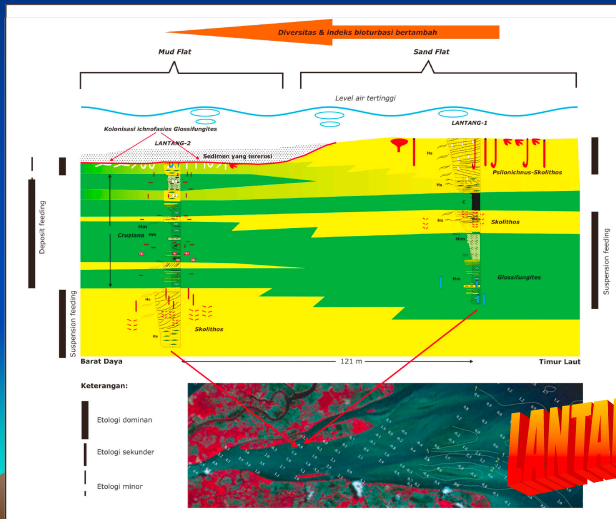
Presenter's Notes:

At the crest of the submerged longitudinal bar sand , we cored a very pronounced cross-bedded fine- to medium-grained sandstone at the top, with burrowing by organisms; at the base of the core is organic mud with sand-silt interbed, indicating tidal action.

The megaripples developed at the surface of this bar clearly demonstrate the work of tidal action, with pronounced interference rounded top ripples, as shown on the photograph in the lower right. These bedforms were responsible of the development of cross-bedding in the upper sand in the core.

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MAHAKAM DELTA INACTIVE LOBE LOWER DELTA PLAIN – UPPER DELTA FRONT SAND DISTRIBUTION MODEL



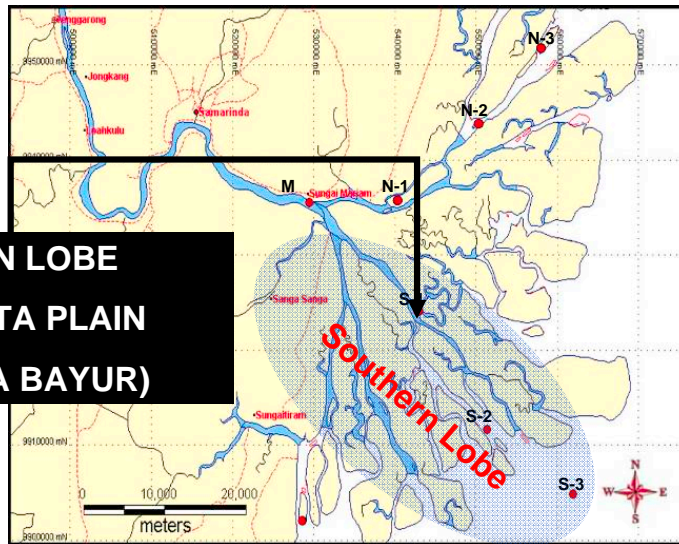
BASED ON BOTTOM GRABBED SAMPLES, SHALLOW CORES, AND BATHYMETRIC CORRELATION

LANTANG ISLAND MODEL

Presenter's Notes: The model that we developed for the abandoned lower delta plain distributary channel of the northern lobe shows the predominance of clays interfingering with sands in this area as a result of tidal action reworking the sands from a previous phase of an active distributary channel. Sand flat - mud flat, tidal sand bar - distributary mouth bar mud flat describe the morphology of this area.

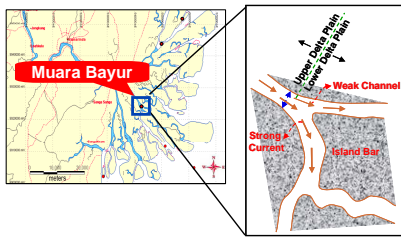
RESULTS

SOUTHERN LOBE UPPER DELTA PLAIN (S1 – MUARA BAYUR)



Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

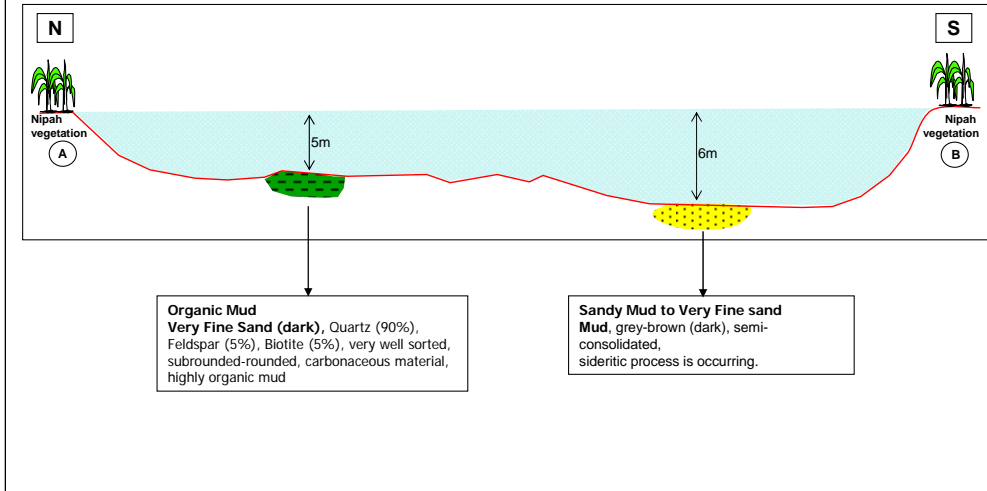
Presenter's Notes: The southern lobe -- the study in Muara Bayur, Datu Island, and Muara Bujit.



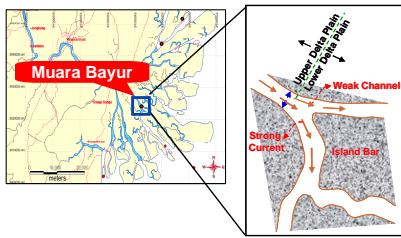
GRAB SAMPLE AND RIVER PROFILE

Location : Muara Bayur

Date : 2007



Presenter's Notes: Grab sample and river profile in 2007, from north to south: organic mud to sandy mud (at 5m) to very fine sand (at 6 m).



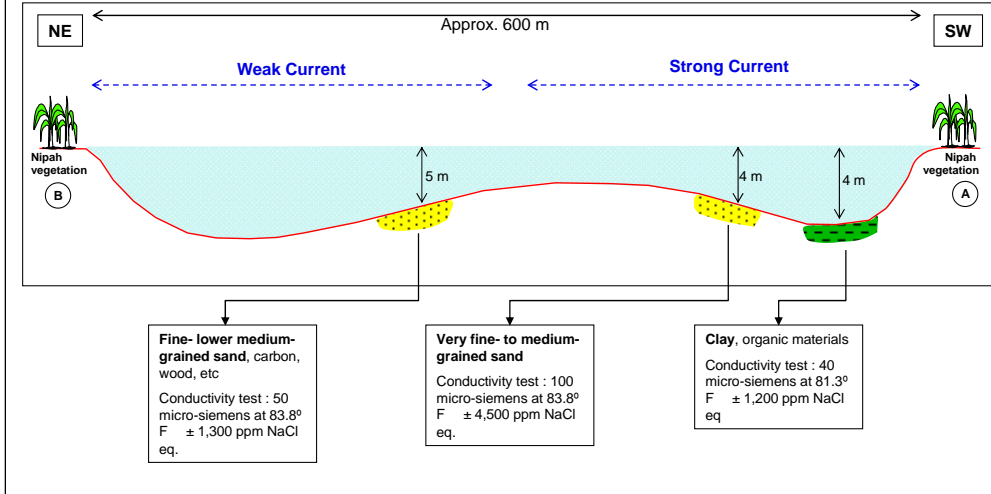
GRAB SAMPLE AND RIVER PROFILE

Location : Muara Bayur

Date : March 25, 2009

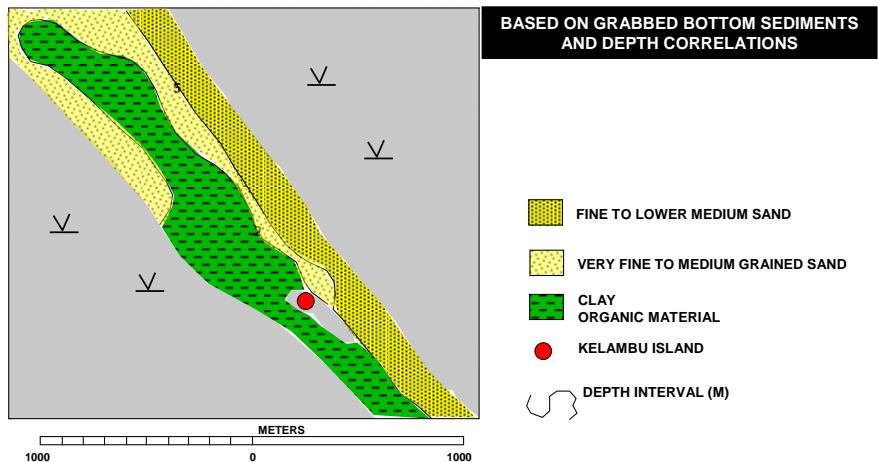
Time : 11.00 AM– 12.30 PM

Weather : Bright



Presenter's Notes: Grab sample and river profile in March 25, 2009, show the grab sample is clay, very fine- to medium- grained sand, and fine- to lower medium-grained sand. The width of channel is 600 m; current is weak and strong. Salinity is 1300 ppm.

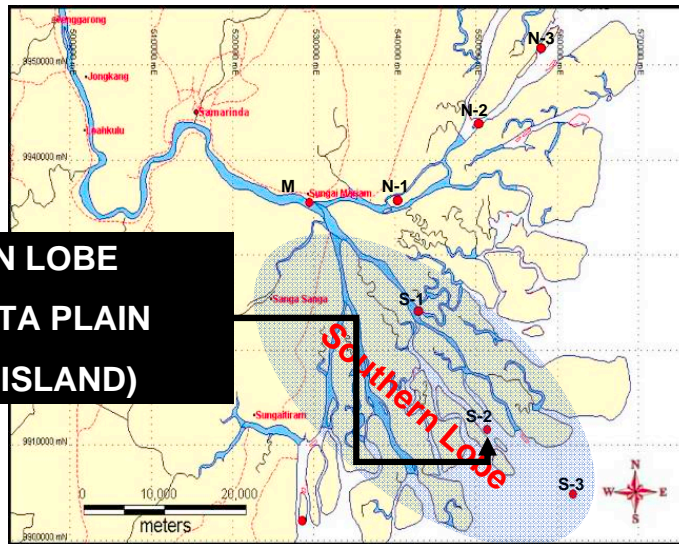
MAHAKAM DELTA ACTIVE LOBE UPPER DELTA PLAIN DISTRIBUTARY CHANNEL SAND DISTRIBUTION MODEL (MUARA BAYUR)



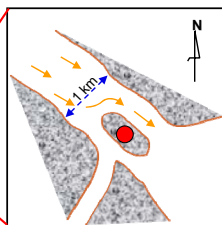
Presenter's Notes: In the upper delta plain distributary channel of active lobe; the clays are deposited in the shallower depth of point bar, indicating normal processes of lateral accretion.

RESULTS

SOUTHERN LOBE LOWER DELTA PLAIN (S2 – DATU ISLAND)

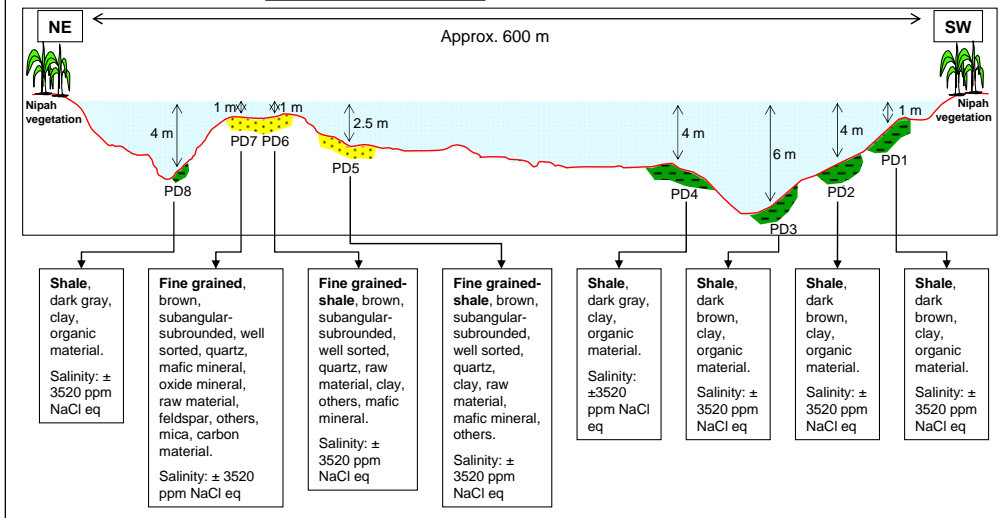


Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

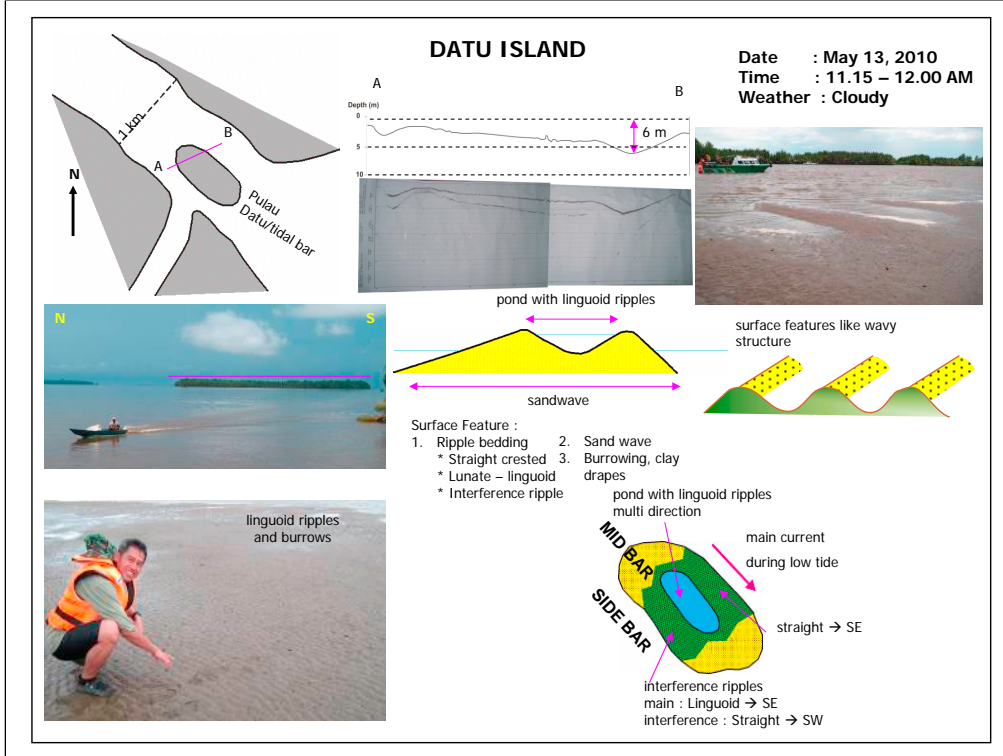


GRAB SAMPLE AND RIVER PROFILE

Location : Datu Island
 Date : 07th Aug 2010
 Time : 02.09 Am
 Weather : Cloudy

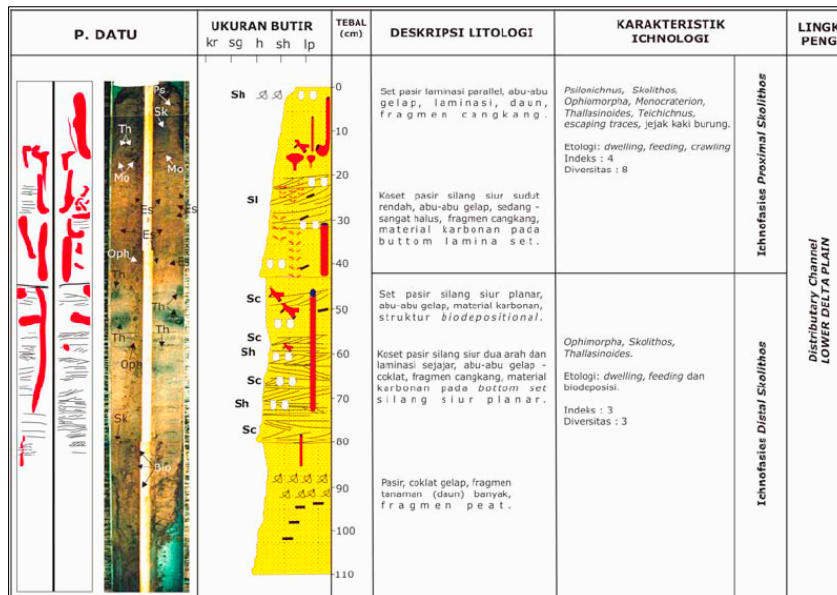


Presenter's Notes: Some clays are present in the deep thalweg of this lower delta plain distributary channel complex.
 The salinity in this area only reaches as much as 3500 ppm NaCl equivalent.

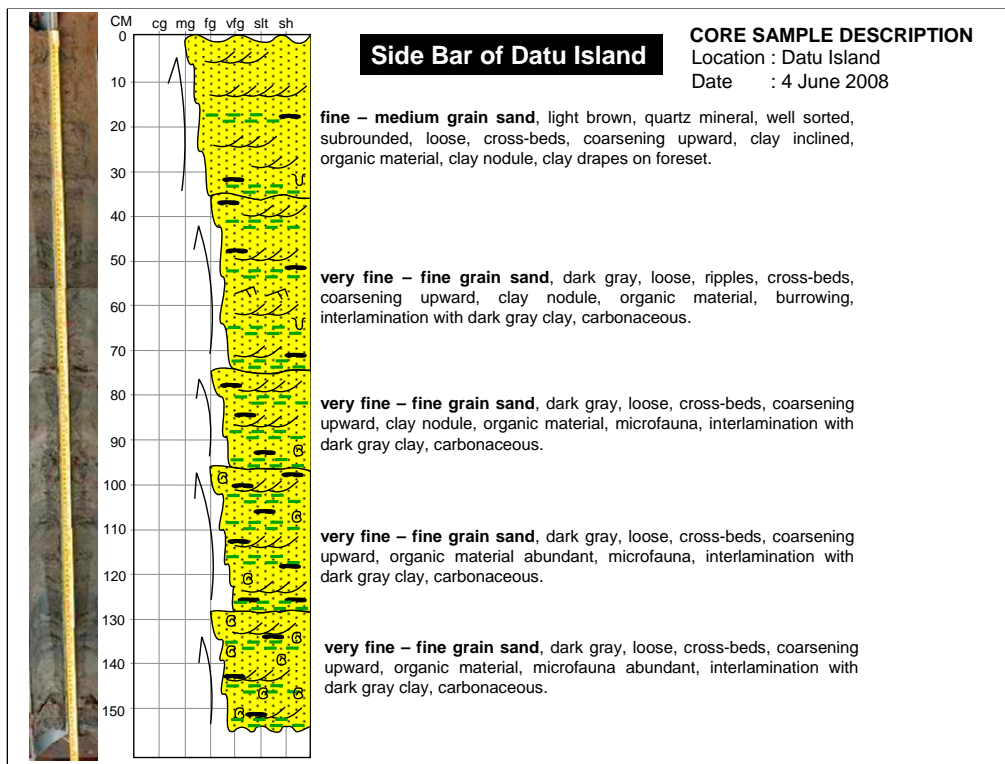


Presenter's Notes: The surface features observed in the lower delta plain distributary channel sands are mega-ripples, sandwaves with small scale ripples on top of them, and many interference ripples. These are responsible for the cross bedding structure we seen in the cores.

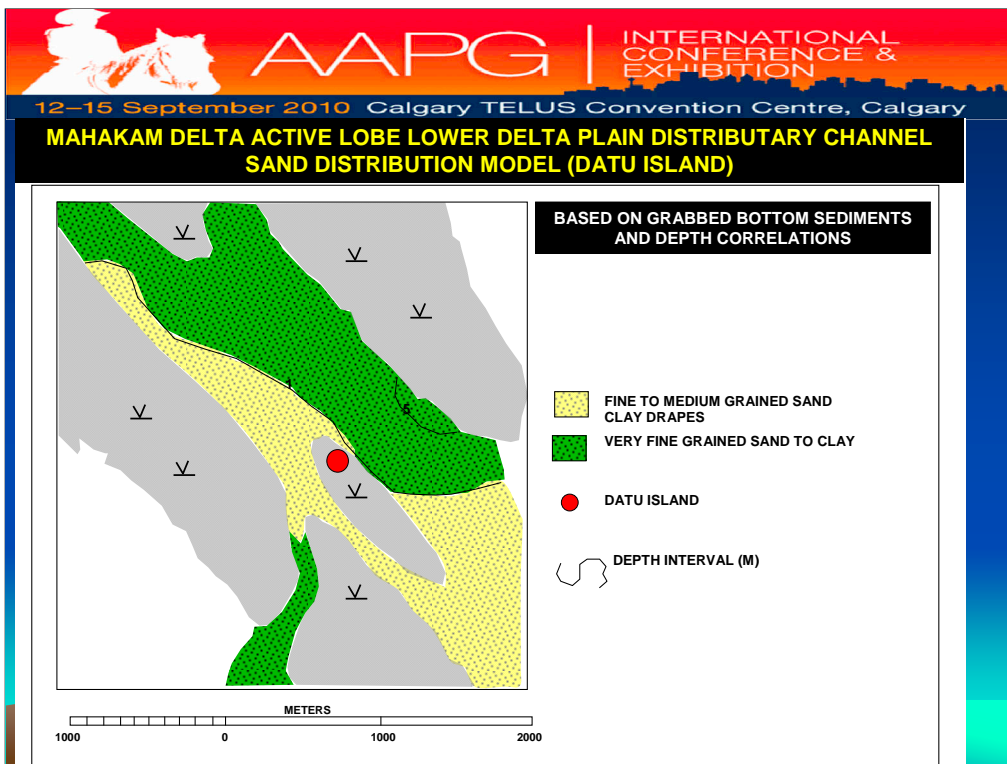
PROFILE OF *MID BAR* IN DATU ISLAND



Presenter's Notes: In the mid-bar core we found fining upward, cross-bedded sandstone with numerous burrows and clay drapes.



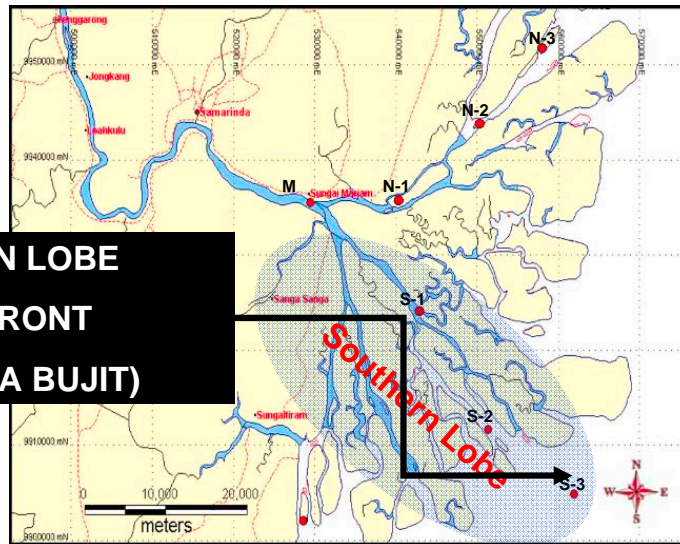
Presenter's Notes: Core sample description in June 4, 2008: coarsening upward, from bottom very fine- to fine-grained sand→microfauna abundant, very fine- to fine-grained sand→microfauna, very fine- fine-grained sand, very fine- fine-grained sand, fine- to medium-grained sand--→clay drape.



Presenter's Notes: Bypass zone in thalweg area, 1KM width of channel.

RESULTS

SOUTHERN LOBE DELTA FRONT (S3 – MUARA BUJIT)

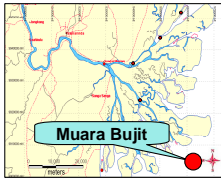


Note : M : Maryam River N-1 : Miang Island N-2 : Burung Island N-3 : Lantang Island
 S-1 : Muara Bayur S-2 : Datu Island S-3 : Muara Bujit

Presenter's Notes: Muara Bujit (southern lobe – delta front).

MUARA BUJIT

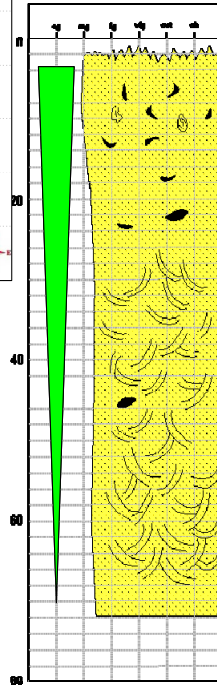
Date : May 13, 2010
Time : 14.00 – 15.00 PM
Weather : Cloudy



Tidal influence at Muara Bujit area

Presenter's Notes: Surface feature of distributary mouth bar, megaripples , sand waves with fine- to medium-grained sands.

Date : 2007



fine sand, brown (light), with quartz (90%) feldspard (10%), well sorted, very rounded, content of shell fragment, burrow structure.

Presenter's Notes: Core sample description in 2007: from bottom fine sand, fine sand, fine sand, medium-fine sand, medium-fine sand, medium sand.

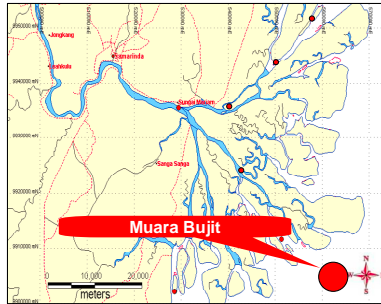
CORE SAMPLE DESCRIPTION

Location : Muara Bujit

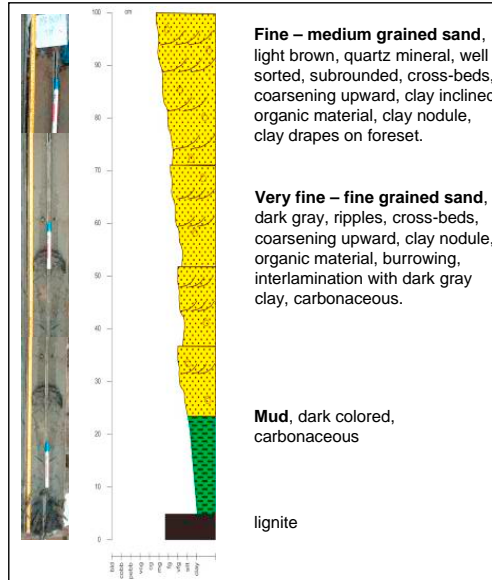
Date : March 25, 2009

Time : 15.30-17.00 PM

Weather : Cloudy

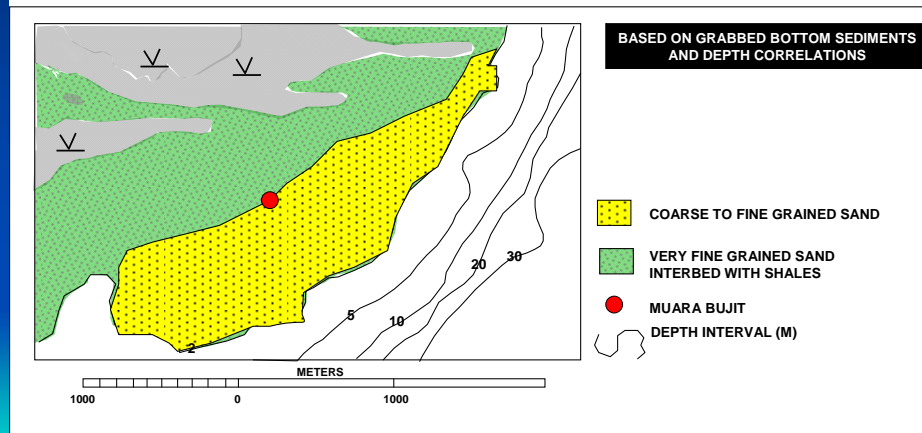


Distributary mouth bar



Presenter's Notes: Another view of one of the cores that we obtained in this area; in this case we have lignite – carbonaceous mud at the base of the core.

MAHAKAM DELTA ACTIVE LOBE UPPER DELTA PLAIN DISTRIBUTUTARY CHANNEL SAND DISTRIBUTION MODEL (MUARA BAYUR)



Presenter's Notes: 1 KM wide, minimum 3 KM long.



AAPG

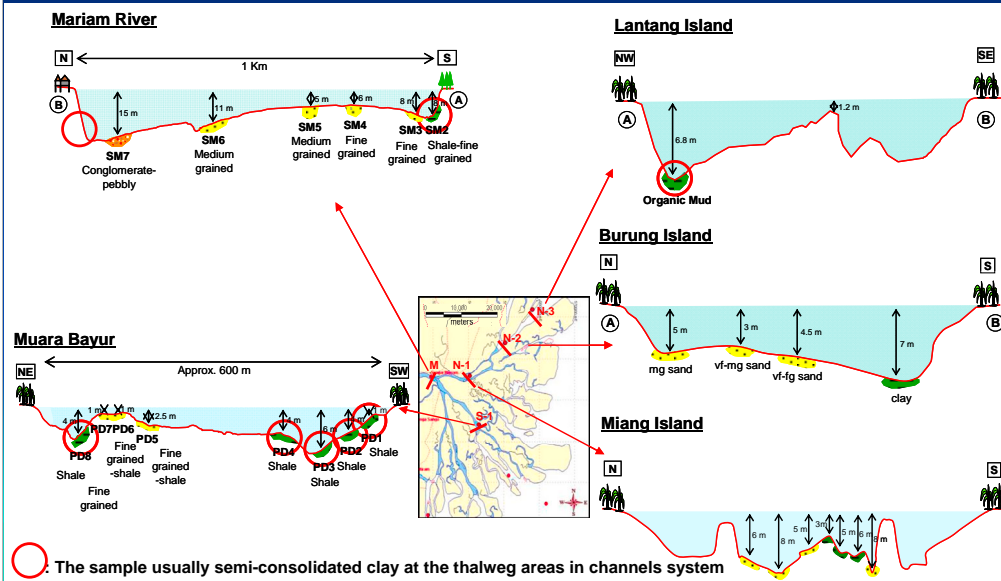
INTERNATIONAL
CONFERENCE &
EXHIBITION

12–15 September 2010 Calgary TELUS Convention Centre, Calgary

THE DYNAMICS OF MAHAKAM DELTA COMPONENTS

12–15 September 2010 Calgary TELUS Convention Centre, Calgary

SEMI-CONSOLIDATED CLAYS IN THALWEG AREAS

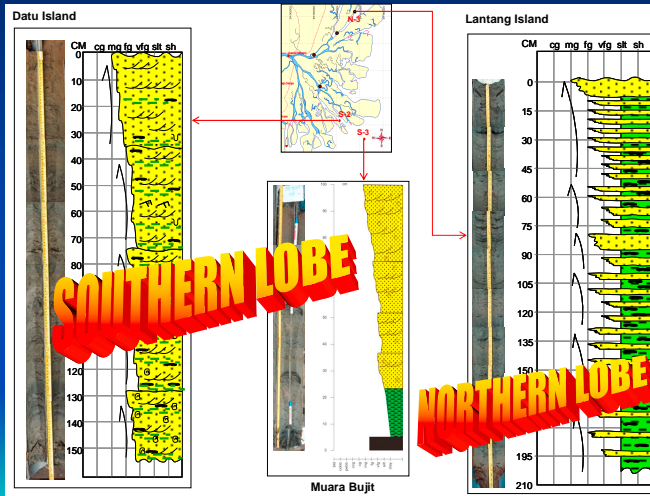




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TIDAL BAR
SANDS IN
NORTHERN
ABANDONED
LOBE AREA
**HAVE MANY
MORE CLAY
DRAPES** THAN
THE SAME
SANDS IN THE
SOUTHERN
ACTIVE LOBE



AAPG

INTERNATIONAL CONFERENCE & EXHIBITION

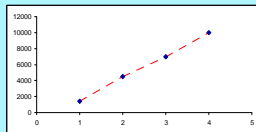
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SALINITY DATA -----→ PETROPHYSIC APPLICATION : R_w

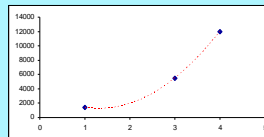
No.	Location	Salinity (ppm)			
		2007	2008	2009	
		Nov	Jun	Mar	Aug
1	Head of passes		1200	1400	111
2	Muara Bayur	>1000	4500	4500	3000
3	Datu Island		7000	7000	8400
4	Muara Bujit		10000		
5	Burung Island			5500	
6	Lantang Kecil Island			19000	
7	Lantang Besar Island		12000		

NORTHERN
ABANDONED LOBE
**IS MORE SALINE,
WITH DRASTIC
INCREASE
DOWNSTREAM,
THAN SOUTHERN
LOBE**

Salinity curve on southern lobe



Salinity curve on northern lobe

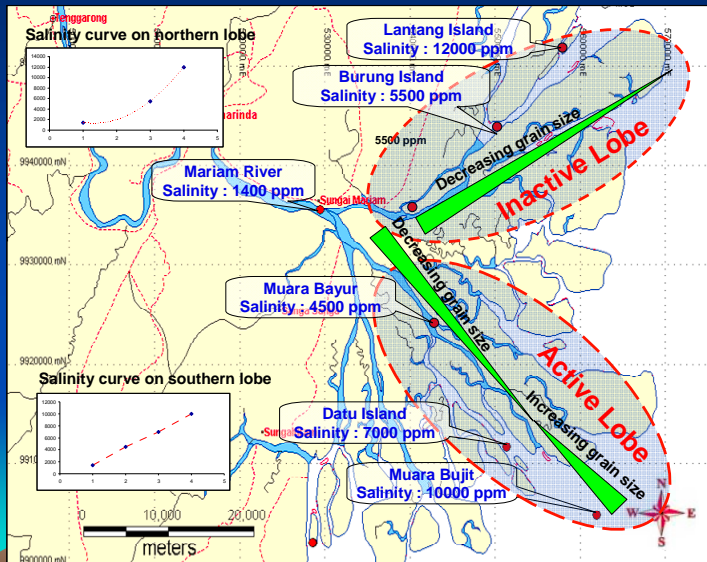




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**LOBES DIFFERENT
CHARACTERISTIC
SUMMARY**

CONCLUSIONS

Thalweg in channel system usually has semi-consolidated clay, as opposed to sand, indicating *tidal action in the northern lobe and sediment bypass in the southern lobe.*

The grain size decreases on the river bed from the head of passes to delta front in the northern lobe, but it was not apparent in the southern lobe, where there was a *distinct anomaly of coarser grain size from lower delta plain to the delta front area (this is due to sediment bypassing).*

Shallow core data in the lower delta plain were generally characterized by clay drapes, suggesting tidal process was operational in both areas of northern and southern lobes, with *northern lobe becoming more intensively tidal influenced than the southern lobe*

The salinity data in the water and sediments both showed an increasing trend from upstream to downstream, with the *northern lobe being more intruded by the seawater profiles.*

Updip shale-out trap of delta front mouth-bar sands may be worth pursuing, as well as new model of fluvial, in contrast to delta plain sand geometry, with respect to clay plugs and edge-of-channel.

ACKNOWLEDGMENTS

We acknowledge to GDA and ETTI team for their support
and contributions in this paper

THANK YOU