Sedimentary Facies of the Mahakam Delta: Comparison between the Modern and the Miocene

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Introduction

The Mahakam Delta is located on the eastern coast of Kalimantan Island (Fig. 1), some 50 km south to the equator. The coastline of this area is oriented NNE-SSW, and is open to the Makassar Straits which are about 200km wide, separating Kalimantan and Sulawesi.

Field studies in the modern Mahakam Delta have been conducted by several workers. G. P. Allen, in 1974, conducted fieldwork to acquire a preliminary understanding of the sedimentary framework and characteristic facies distribution. The work was based on field observation, sediment sampling by using a Berthois hand dredge (surface sediment sampling) and coring devices (up to 2-4 metres depth), and water samples. In 1975, a second phase of study was conducted involving a coring program on the modern Mahakam Delta (Allen, 1974; 1976). The objective was to study the major geometrical characteristics and facies patterns of the formations. Additional coring program was conducted in 1976 (Allen, 1976), which consisted of a number of shallow auger holes of up to 10 metres depth, and surface sediment samples. Allen (1992) conducted fieldwork in the large mouth bar system adjacent to Muara Bujit. The study was based on surface sediment sampling and shallow coring (up to 6 metres depth) to determine the geometry, facies patterns and internal architecture of a distributary mouth bar. The second phase of this work was done in 1993 and focused on the crest of the active distributary mouth bar to determine the detailed facies pattern, reservoir architecture and heterogeneity within the bar. The lengths of the vibracores used in this work were insufficient to determine in detail the thickness and geometry of the bar system. Therefore, coring campaign was again conducted in 1997, with drilling platform capable of drilling to depths of 20m.

Results of several studies conducted in the modern Mahakam sediments were then compared with facies analysis of the Miocene cores to understand any differences in terms of depositional energy between the modern and the Miocene sediments.

The Modern Mahakam Delta

Present-day Mahakam Delta is fed by the Mahakam River, flowing from the central highlands of Kalimantan and debouch into the Makassar Strait. About 50-60m thick of sediments have been deposited on top of the older Pleistocene sediments. Modern Mahakam Delta covers an area of some 10.000km2 (Allen & Chambers, 1998) and is about 50km long, as measured from the delta front to the first bifurcation of the Mahakam River at Sanga-sanga (Gastaldo et al., 1995). The sediment source is derived from sediments and basic igneous rocks of the Kuching High. The modern delta developed following a decline in the rate of the Holocene transgression, about 5000 years ago (Allen et al., 1976). The mean wave amplitude is some 0.6m and tidal amplitude range between 1.2m to 2.8m. The modern Mahakam delta extends seaward on the shelf up to some 25km from the shelf break (Allen & Chambers, 1998). In general the sediments were formed by low energy traction deposits.

The Mahakam shelf is very active and is dominated by the interplay of siliciclastic and carbonate buildups (Robert & Sydow, 1996). The carbonate deposits occur in the middle and outer shelf, while the inner shelf is dominated by Holo-

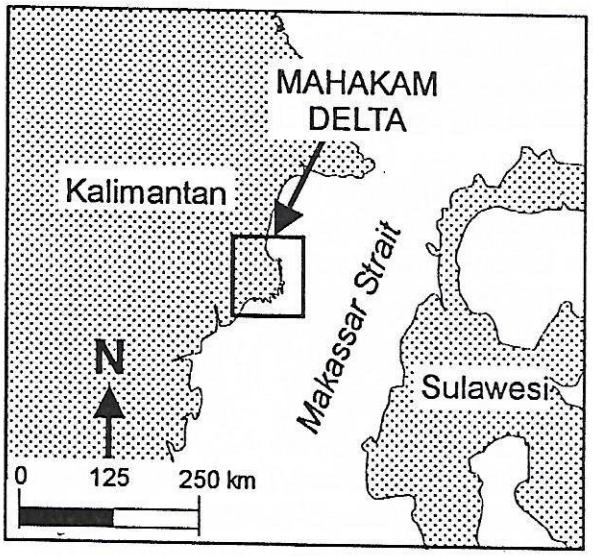


Fig. 1. Location map of the modern Mahakam Delta, East Kalimantan.

cene deltaic sediments. The growth of Halimeda carbonate is apparently slowing down and is currently being overlain by the progradation of deltaic sediments.

Distributary Channel

The distributary channel contains either thick-bedded, clean cross-stratified sand or thinner-bedded muddy and ripple-laminated sand (Allen & Chambers, 1998) and extends to the delta front. Features characteristic of fluvial flood dominated delta such as alluvial levees and crevasse splays, are totally absent (Allen & Chambers, 1998). The sediments were formed by lower-flow regime conditions. Though the channel thalweg exhibits a meanderig pattern, the distributary channels are straight. They are about 1km wide, and bifurcate downstream every 10-15km (Allen & Chambers, 1998). Channel depth can attain up to 15m.

The sediment samples from the delta front distributary channels contain mainly mud and silty mud, and in contrast to the other delta front sediments, have an abundance of clay and pebbles and ferruginous concretions (Wiweko, 1998).

Tidal channels are generally not connected to the distributary channels and exhibit high sinuous tidal channels. These tidal channels can attain up to 18m depth and are stable over a period of at least 50 years (Allen & Chambers, 1998).

Distributary Mouth-Bar

Sediments in the delta front comprise fine to medium, well-sorted sand to silty and muddy sand, with the cleanest sand accumulates on the crest of the mouth bars. As in the channels, no coarse sand occurs and the sands are generally bioturbated or exhibit small-scale current and wave ripples. Upper flow regime structures, such as parallel lamination, are lacking suggesting the energy is relatively low. Coring campaign conducted in 1997 observed thin (10cm) fine sand showing parallel lamination in a mouth bar facies (Wiweko, 1998). But this feature found only in one of the core and it was not found in other cores. The distributary mouth bar consists of multistorey bar systems with maximum sand thickness of 6 metres.

Prodelta

The prodelta composed mostly of massive mud with scattered bioturbation. The total thickness of the prodelta can attain 30 to 60m (Allen & Chambers, 1998).

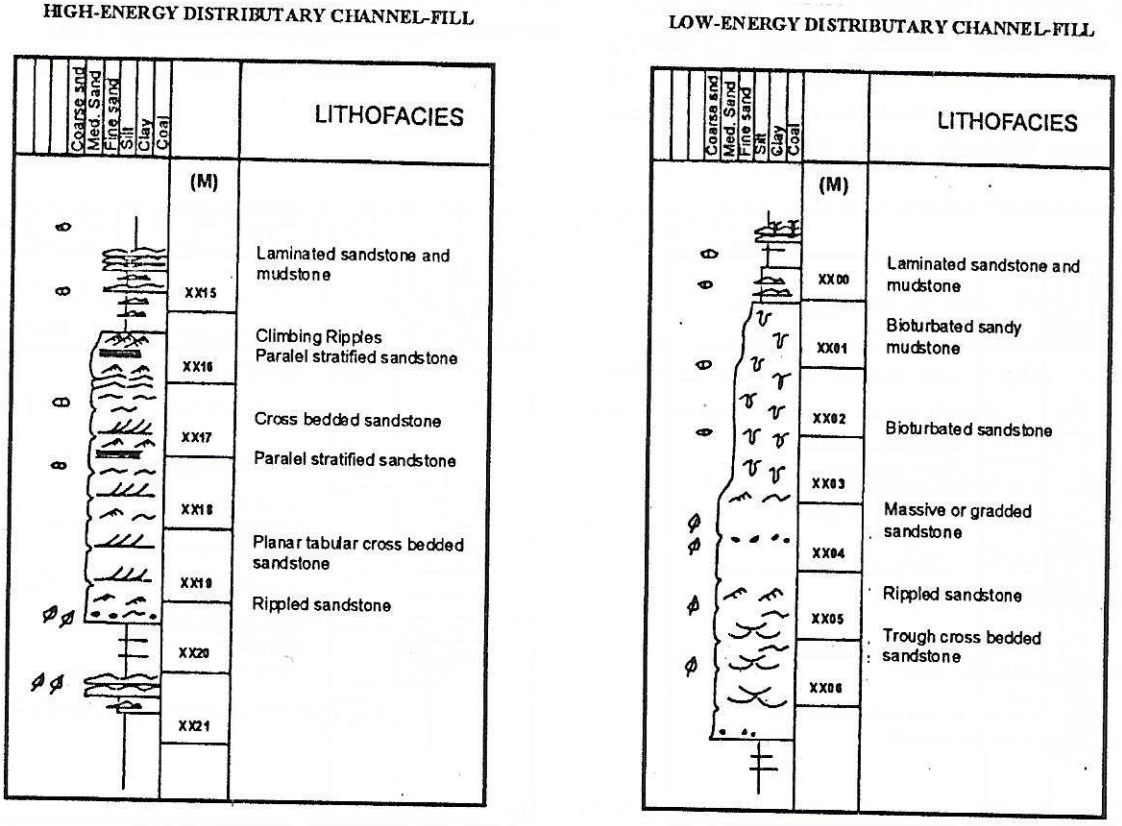


Fig. 2. A comparison of high and low energy distributary channel-fill.

Paleo Mahakam Sediments

In contrast to the modern sediments, which are lacking of upper flow regime structures, the Upper Miocene sediments exhibit both lower and upper flow regime structures. The grain size is also slightly coarser compared to that of the modern. In general the sediments were formed by a combination of traction and suspension (density current). Bouma-like sequence (facies B and C) occurred frequently both in the channel as well as in the distributary mouth bar facies. No wave structures have been observed suggesting low wave energy, and no obvious indication of the occurrence of high tidal energy suggesting low to moderate tidal energy. The influence of combined tide/fluvial processes resulted in unique features of the facies.

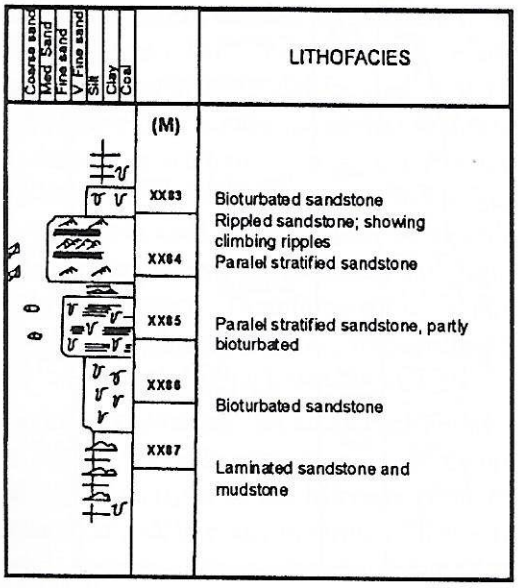
Distributary Channel

Unlike their equivalent in the modern delta, the Upper Miocene delta front distributary channel comprises mostly sandstone. The grain size ranges from fine to medium sand. Coarse-sand is observed mostly at the base of the channel. Their facies patterns indicate that they were formed by high-energy as well as low energy suspension and traction currents. Upper-flow regime structures such as parallel lamination with climbing ripples occurred frequently in high-energy dominated distributary channels. Whilst low-energy channels are characterised by the absence of flood deposits. In general, the thickness of these distributary channels ranges from 5 to 15m. In the proximal part stacking channels can attain some 30m.

Distributary Mouth Bar

These deposits consist of fine to medium-grained sand with variable amount of mud and bioturbation. As in the distributary channel, the facies patterns of distributary mouth bar also indicate the occurrence of high- and low-energy traction and suspension. The sedimentary structures and bedding patterns of the Upper Miocene mouth bars are very different from those observed in the modern delta. The mouth bars range in thickness up to 7m and are typical upward coarsening and thickening. Generally, the base and the top of the bar section are intensively bioturbated, obliterating the bedding. Parallel stratification with climbing ripples on top similar to Bouma sequence B and C are observed in high-energy mouth bar, suggesting the occurrence of episodic pulses of high-energy transport and rapid deposition. Distributary mouth bars dominated by flaser bedding, lenticular bedding and ripple laminations with no indication of flood deposits are also observed. Tabular planar cross stratification with bedsets range between 5 to 15cm occurs in places. These sedimentary structures indicate predominance of bottom traction currents. The absence of upper-flow regime structures could reflect low energy fluvial setting.

HIGH-ENERGY DISTRIBUTARY MOUTH BAR



LOW-ENERGY DISTRIBUTARY MOUTH BAR

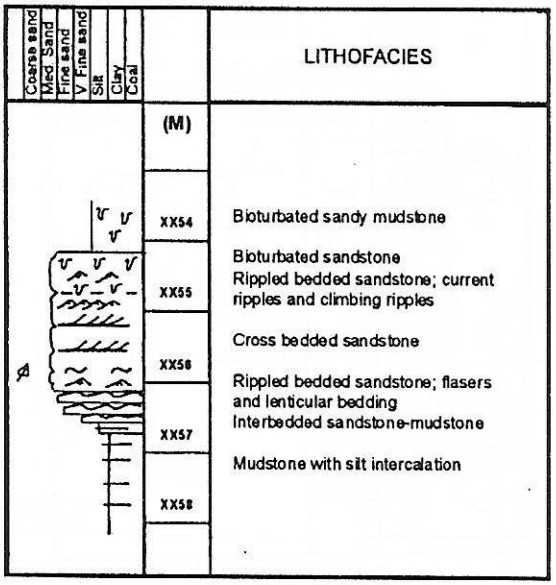


Fig. 3. A comparison of high and low energy distributary mouth bar..

Prodelta

The prodelta sediments generally comprise muddy sediments, with massive mudstone and interbedded mudstone and sand laminae. Soft sediment deformation and slump structures are common. Thinly inter-bedded mud and sand similar to the "rhythmites" described by Reineck & Singh (1980) were observed. These "rhythmites" are 30cm thick and exhibit graded sand to mud in the order of millimetres, with minor scouring. The rhythmites are thought to represent deposition in a prodelta down dip to a major fluvial distributary.

Conclusion

The modern sediments of the Mahakam River are characterised by fine-grained sediments and a general lack of high-energy fluvial-flood deposits. Whilst, the Upper Miocene sediments are characterised by slightly coarser-grained size and the occurrence of high-energy current deposits. The high-energy deposits generated by fluvial-flood occurred in the form of Bouma-like sequence (facies B & C). This distinct characteristics of facies between the modern and the Upper Miocene sediments suggest differences in current energy. The sediments in the modern delta, therefore, have been deposited in lower energy conditions, whereas the Upper Miocene sediments have been deposited in higher energy conditions dominated by fluvial flood events.

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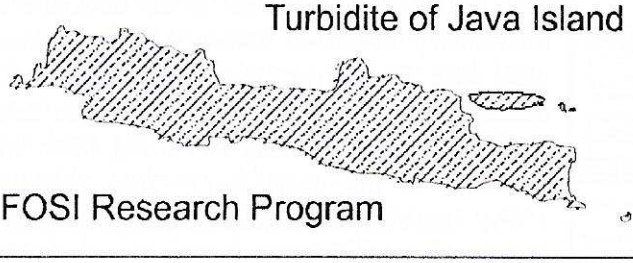
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