Comparison of Paleo-Mahakam Delta with Other Delta Systems

F. Hasan Sidi (VICO Indonesia)

The Middle to Upper Miocene delta system in Kutai Basin (Wiweko & Giriansyah, 1999; Sidi & Payenberg, *in prep.*) is compared with several published delta models in this article. The modern day Mississippi has been taken to represent fluvial-dominated deltas, Colorado delta in the Gulf of California (Meckel, 1975; Dalrymple, 1992) for tide-dominated delta, and the Rhone delta (Oomkens, 1970; Fisher et al., 1969) for the wave-influenced comparison.

Processes & Facies Comparison

A totally fluvial flood-dominated non-tidal delta model would not suit the Middle Miocene depositional model even though there are a lot of similarities (Table 1) with the modern day Mississippi delta (Figure 1). Although there is a strong fluvial influence in the Middle Miocene deltaic succession, the scarcity of high-energy fluvial signature, such as the abundance of climbing ripples in overbank splay deposits (Coleman & Wright, 1975) or in the middle mouth bars (Coleman, 1981) distinguishes this succession from the fluvial dominated deltas.

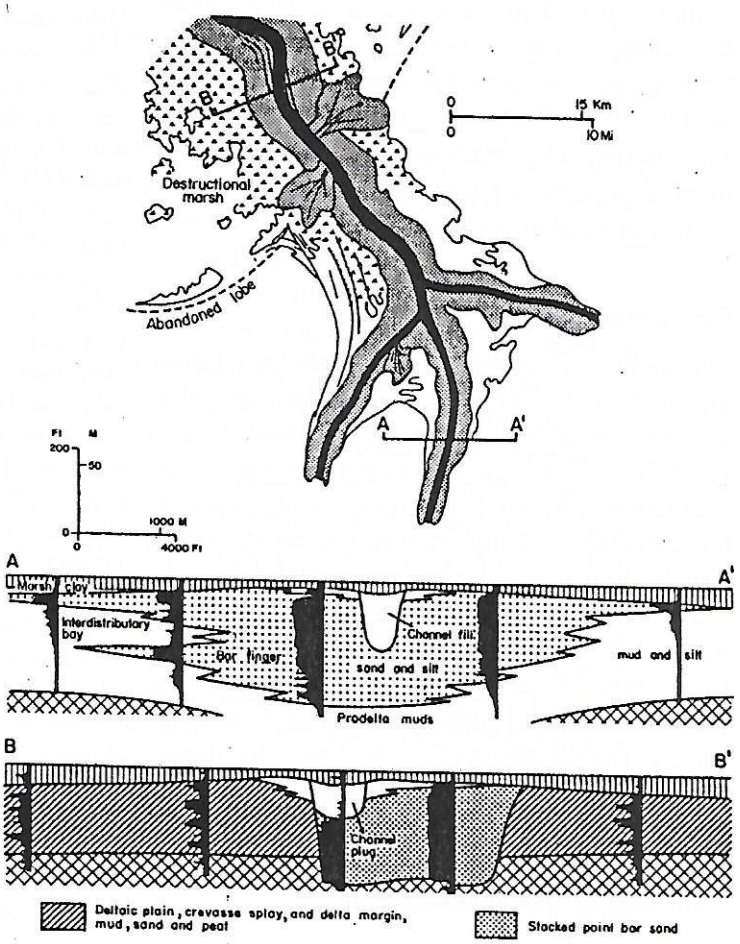


Fig. 1. Modern Mississippi Delta facies map with cross sections showing the difference between the proximal and distal part.

PUBLISHED MODELS	SIMILARITIES
Modern Mississippi Delta System	• Rectilinear distributaries flanked by levees and separated by interdistributary bays and marshes • Erosive and unidirectional trough cross-bedding (lithofacies Sc_e) and parallel stratification (lithofacies Sp) in the channels • The upper portion of the channel mouth bar is locally cut out and replaced by a complex network of distributary channel fills. • The occurrence of fluvial overbank and flood deposits • Soft sediment deformation features are common and involve large proportions of the delta front sediments
Colorado River Delta	• Overall tidal facies is predominated by abundant of clay laminations and drapes, flaser and lenticular beddings and probably sigmoidal cross-bedding.
Rhone Delta	• No significant similarities
Modern Mahakam Delta	• Distributary channels which exhibit a seaward fining gradient with medium to coarse sand at the landward limit of the delta, grading to medium and fine sand in the lower delta plain • Distributary mouth bars also have facies similarities of fine and muddy sand • Obvious absence of large-scale cross laminations in all distributary channel facies • Lobate morphology and abundance of distributaries • Extensive, relatively flat, and marshy delta plain

Table 1: Similarities of Middle Miocene Delta with other published models.

A pure tidal-influenced model could also be discarded due to the lack of high-energy tidal facies and structures. Also, in the case where very strong tidal occurred, then there would be no flood deposits recorded (Allen & Chambers, 1998). The other argument is the thickness of distributary sandstone bodies which decreases basinward in contrast to the proposed tidal-dominated model, such as the Colorado delta (Figure 2), which exhibits increasing width and thickness of the distributary sands (Meckel, 1975). However, some tidal influences do exist.

Wave energy in the Miocene was, for practical purposes, considered nil as there are no wave

PUBLISHED MODELS	DIS-SIMILARITIES	
	Published Model	Middle Miocene Delta
Modern Mississippi Delta System	• Elongate morphology • Narrow delta plain • Have high-energy fluvial signature, such as the abundance of climbing ripples in overbank splay deposit in the middle mouth bar	• Lobate morphology • More extensive delta plain • No abundance of climbing ripples in overbank splay deposit nor in the middle mouth bar are observed
Colorado River Delta	• The effect of river floods will be secondary since tidal reworking will rework flood deposits and little of them will be preserved. • Tidal indicators in delta front sands include herringbone cross-bedding, tidal bundles, and reactivation surfaces • Increase of width and thickness of the distributary sands basinward	• Significant flood deposits observed • Tidal indicators in delta front sands only include association of clay drapes and abundant of flaser and lenticular beddings • The thickness of distributary sand bodies decreases basinward
Rhone Delta	• The presence of wave-dominated shoreface deposits which are characterised by wave-formed structures, parallel stratification, hummocky cross-stratification, wave ripples, storm scours, and storm graded beds • Delta plain morphology are arcuate to cuspate • Distributaries are fewer in number • The delta front sands form a broad, continuous sheet or apron and reflect a greater impact of marine processes	• No wave-built deposits, e.g. beach, shoreface, or storm deposits are observed • Lobate morphology • Abundant clusters of distributaries • Delta front sands only reflect minor effect of wave
Modern Mahakam Delta	• Non-flooding fluvial discharge system	• Some indications of alluvial flood deposits and channel-bank failures • Abundance of coal or plant detritus in most sand body

Table 2: Dissimilarities of Middle Miocene Delta with other published models.

deposits observed, such as beach, shoreface, or storm deposits or beach ridge sandstone along the front and margins (Fisher et al., 1969) as in the modern Rhone delta (Figure 3). In the delta plain interdistributary, there are no shell beds or thin beds of algal limestones like the modern day Rhone delta (Oomkens, 1970), although the model has abundant plant detritus similar to a modern wave-influenced delta. The only wave influence recorded is probably the accumulation of plant fragments and detrital peat along the shorelines (distributary mouth bars) which was locally winnowed along with the sands. With the abundance of bioturbation, the wave energy could be rated as relatively low compared to the Niger delta where bioturbation is uncommon in the delta front (Allen, 1970).

The most comparable model is the modern day Mahakam delta with a mixed fluvial and tide-influenced delta systems. There are some similarities in the sedimentary facies of distributary channels, which exhibit a seaward fining gradient with medium to coarse sand at the landward limit of the delta, grading to medium and fine sand in the lower delta plain. The distributary mouth bars also have facies similarities of fine and muddy sandstone (Allen et al., 1979).

The difference with modern day conditions is the relatively higher fluvial energy (Table 2). In all Middle to Upper Miocene Paleo-Mahakam distributary channel facies, large-scale cross beddings are obviously absent, but there are some indications of high-energy alluvial flood deposits such as parallel stratification. Alluvial flood deposits have not been reported from the modern day Mahakam delta (Allen et al., 1979; Allen & Chambers, 1998)

The other dissimilarities with the Modern Mahakam is the abundance of coal both *in situ* and reworked (detrital) in all the Middle to Upper Miocene delta plain deposits versus their absence in the modern delta. The abundance of coal in the Miocene infers an intense covering of potentially coal-forming peats in the delta plain or even landward in the floodplain. The delta plain conditions are similar to the modern day examples of Mississippi (Kosters et al., 1987) or Rajang Delta, Serawak (Staub & Esterle, 1993). Equatorial climate might enrich the fine-grained sediments with plant debris derived from palms and mangroves (Allen et al., 1979).

The lack of in-situ peat in the modern systems can be attributed to the effects of tides which disperse suspended silt over the entire delta, imped-

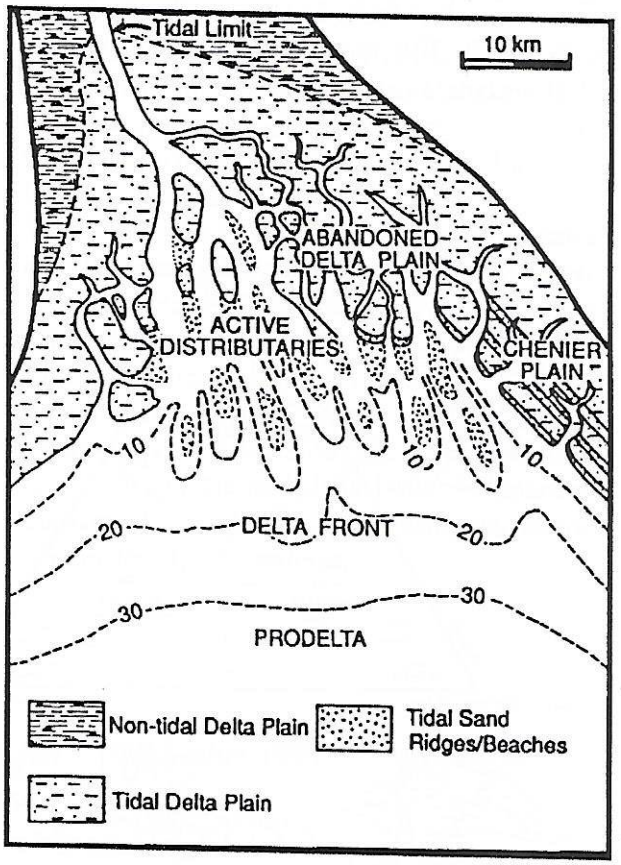


Fig. 2: Schematic map of tidal delta (Dalrymple, 1992) based on Colorado river delta, the Ganges, and the Ord. Note the extension of tidal sand ridges well in front of the delta-top distributary channels and tidal flats.

ing the formation of low ash peat. Thus, until the delta plain or part of the delta plain is abandoned, the delta plain will not be covered with a peat swamp. However, up to present time, progradation of the modern systems has occurred over the entire deltaic shoreline and there has not been any lobe abandonment (Allen & Chambers, 1998).

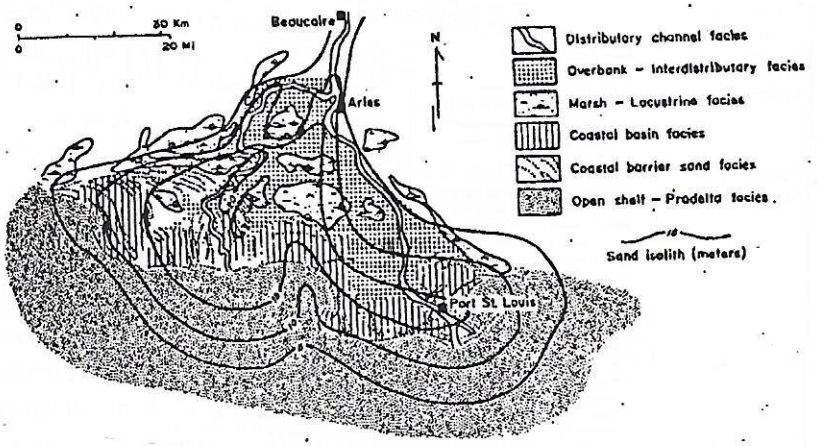


Fig. 3. The Rhone delta which represents the wave-dominated system (Fisher et al, 1969). Note the smooth cuspate to arcuate delta front as a result of wave reworking (longshore drift).

Morphology

By analysing the superposition and lateral distribution of the distributary channel facies from various reservoir maps, the Upper to Middle Miocene Paleo-Mahakam delta would have similar morphology with the modern day systems, i.e. lobate morphology with branching distributary complex and numerous distributary channels. Recent work even suggests that the river systems have been fixed in the same position since the Middle Miocene (Allen & Chambers, 1998). This implies that (1) both the Upper-Middle Miocene and the modern delta are approximately in the same position and (2) the deltaic depocenter of the Kutai Basin since the Middle Miocene has remained in the same position on the coast.

Reservoir Geometry

In general, the reservoir geometry of the Paleo-Mahakam delta shows a lot of similarities with its modern system. The distributary channels are relatively straight with the sandstone in the delta plain distributaries form narrow and rectilinear sandstone belts. The width to thickness ratio is also similar; the Miocene ranges from 40:1 to 130:1 whereas the modern systems range from 80:1 to 120:1 (Allen & Chambers, 1998). The individual distributary mouth bars of both systems forms triangular to lobate sandstone deposits with total thickness of 3-7 metres. The only difference of reservoir facies is the occurrence of crevasse splay in the Miocene. The crevasse splays, features characteristic of fluvial flood-dominated deltas, are totally absent in the modern Mahakam and the delta plain consists everywhere of a muddy marsh surface (Allen & Chambers, 1998).

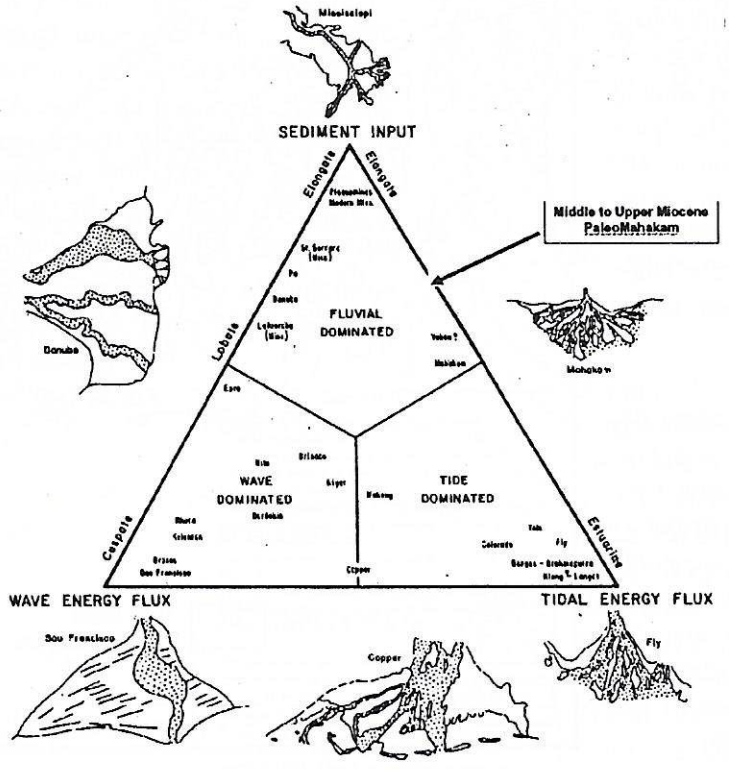


Fig. 4. Ternary diagram of deltaic system (Galloway, 1975) which put the Middle to Upper Miocene system slightly higher to the fluvial end from the Modern Mahakam.

Conclusions

Based on those comparisons, the Middle Miocene depositional model could be placed in the flu-

vial-dominated delta (Figure 4) in the ternary plot developed by Galloway (1975) with tidal influence slightly less than the modern Mahakam. The occurrence of flood deposits in some distributary channel fills and features such as alluvial levees and crevasse splays, although only recognised from the well-logs, pushes this model slightly towards the Mississippi end. The morphology is interpreted to be lobate since there are clusters of distributary channels for each deltaic cycles.

References

Allen, G.P., Laurier, D., & Thouvenin, J. 1979. *Etude Sedimentologique du Delta de la Mahakam*. Total Compagnie Francaise des Petroles, Paris.

Allen, G.P. and Chambers, J.L.C., 1998. Sedimentation in the modern and Miocene Mahakam Delta. *Indonesian Petroleum Association*, 236p.

Allen, J.R.L. 1970. Sediments of the Modern Niger Delta: A Summary and Review. *In* Morgan, J.P. & Shaver, R.H. eds. *Deltaic Sedimentation Modern and Ancient*, SEPM Special Publications #15, pp. 138-151. Society of Economic Paleontologists & Mineralogists, Tulsa.

Coleman, J.M. 1981. *Deltas: Processes of Deposition & Models for Exploration*. Burgess Publishing Co., Texas.

Coleman, J.M. & Wright, L.D. 1975. Modern River Deltas: Variability of Processes and Sand Bodies. *In* Broussard, M.L. ed. *Deltas - Models for Exploration*, pp. 99-150. Houston Geological Society, Houston.

Dalrymple, R.W. 1992. Tidal Depositional Systems. *In* Walker, R.G. & James, N.P. eds. *Facies Models - Response to Sea Level Change*, pp. 195-218. Geological Association of Canada, Ontario.

Fisher, W.L. 1969. Facies Characterisation of Gulf Coast Basin Delta Systems, with Some Holocene Analogues. *Transactions - Gulf Coast Association of Geological Societies* **19**, 239-261.

Galloway, W.E. 1975. Process Framework for Describing the Morphologic and Stratigraphic Evolution of Deltaic Depositional Systems. *In* Broussard, M.L. ed. *Deltas - Models for Exploration*, pp. 87-98. Houston Geological Society, Houston.

Kosters, E.C., Chmura, G.L. & Bailey, A. 1987. Sedimentary and Botanical factors Influencing Peat Accummulation in the Mississippi Delta. *Journal of Geological Society London* **144**, 423-434.

Meckel, L.D. 1975. Holocene Sand Bodies in the Colorado Delta Area, Northern Gulf of California. *In* Broussard, M.L. ed. *Deltas - Models for Exploration*, pp. 87-98. Houston Geological Society, Houston.

Oomkens, E. 1970. Depositional Sequences and Sand Distribution in the Postglacial Rhone Delta Complex. *In* Morgan, J.P. & Shaver, R.H. eds. *Deltaic Sedimentation Modern and Ancient*, SEPM Special Publications #15, pp. 198-211. Society of Economic Paleontologists & Mineralogists, Tulsa.

Sidi, F.H. & Payenberg, T.H.D., 1999. The Middle To Upper Miocene Paleo-Mahakam Deltaic System Based On Sedimentologic And Stratigraphic Analyses In The Kutai Basin, East Kalimantan, Indonesia. (in prep).

Staub, J.R. & Esterle, J.S. 1993. Provenance and Sediment Dispersal in the Rajang River Delta/ Coastal Plain System, Serawak, East Malaysia. *In* Fielding, C.R. ed. *Current Research in Fluvial Sedimentology*, pp. 191-201. Elsevier, Amsterdam.

Wiweko, A. & Giriansyah, B. 1999. Sedimentary Facies of the Mahakam Delta: Comparison between the Modern and the Miocene. *Berita Sedimentologi*, this volume.

Meeting Calendar

IAGI 28th Annual Meeting; Jakarta, 30 November – 1 December 1999

- Bidakara Hotel, Jl. Jend. Gatot Subroto
- Theme: Towards a higher standard professionalism

AAPG International Meeting Bali2000; Nusadua, October 2000

- Abstract submission deadline: 15 November 1999