Depositional Environments and Stratigraphic Development of the Grand Taman Sari Circuit Outcrop: an Analogue for Transgressive Mahakam Delta Successions

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Abstract

A detailed analysis of the sedimentology and stratigraphy of the Grand Taman Sari Circuit outcrop indicates that there were tide-dominant, transgressive deltaic successions with highly retrogradational parasequence sets in the middle Miocene Mahakam Delta province. A 115 meter thick fluvial succession is overlain by an increasingly marine-upward, 280 meter thick transgressive succession. There are two sandstone facies that have reservoir potential. Fluvial channel sandstones up to five meters thick and less than three hundred meters wide are laterally discontinuous, occasionally stacked and difficult to correlate while back-filled distributary channel sandstones are up to twenty meters thick and more than five hundred meters wide. It is difficult to distinguish between the two sandstone facies in the subsurface because they have similar fining upward log signatures.

Keywords: Transgressive, Fluvial system, Shallow Marine system, back-filled distributary channel

1. Introduction

The Mahakam Delta is regarded as one of the world's best examples of a mixed river-dominated and tide-dominated delta based on its morphology (Galloway, 1975). The traditional view suggests that the modern Mahakam Delta is a progradational deltaic system and that the middle Miocene of the Mahakam Delta province was exclusively progradational deltaic system (e.g. Allen et al. 1998, Trevena 2003, and Cibaj 2008). In contrast, a recent study suggests that the modern Mahakam Delta is being transgressed, is strongly tide-dominated and its morphology is a relic of fluvial morphology that has been partially modified by tidal processes (Salahuddin and Lambiase 2013). Similarly, Nirsal (2010) interpreted a middle Miocene Mahakam Delta outcrop as transgressive and Lambiase et al. (2010) identified transgressive successions in core and on seismic data, indicating that transgressive successions are not restricted to the modern delta. The Grand Taman Sari Circuit outcrop, located in Samarinda province (Fig. 1),

2. Sedimentary Facies and Depositional Environments

Thirteen facies were defined from sedimentary structures, bed thickness and contacts, bioturbation and grain size, sorting and sphericity, plus 25 microfossil and palynology analyses. They include:

- Non-marine mudstone
- Conglomeratic pebbly sandstone
- Interbedded sandstone and non-marine mudstone
  - Stacked medium sandstones
  - Thin bedded coal
  - Cross bedded coarse sandstone
- Shallow marine mudstone
- Alternating sandstone and shallow marine mudstone
  - Bioturbated medium sandstone
  - Cross bedded medium sandstone
  - Alternating HCS sandstone and shallow marine mudstone
    - Bioturbated muddy sandstone
    - Interbedded bioturbated fine sandstone and shallow marine mudstone

Four facies were deposited by a meandering fluvial system. The non-marine mudstone facies is floodplain deposits and the conglomeratic pebbly sandstones are fluvial channel deposits. Crevasse splays deposited the interbedded sandstone and non-marine mudstone and stacked medium sandstone facies.

The other nine facies are associated with marine and marginal marine depositional environments. Cross-bedded coarse sandstone facies represent a back-filled distributary channel and, based on palynology, the thin-bedded coals are mangrove swamp deposits. The remaining facies were deposited in more strongly marine-influenced environments, including tidal sand flats (the alternating sandstone and shallow marine mudstone plus the alternating HCS sandstone and shallow marine mudstone), tidal sand bars (bioturbated medium sandstone and bioturbated muddy sandstone), tidal mud flats (shallow marine mudstone), tidal channels (cross-bedded medium sandstone) and shoreface (the interbedded bioturbated fine sandstone and the shallow marine mudstone facies).

3. Stratigraphic Architecture

Generally, this outcrop can be divided into an older fluvial system and a younger shallow marine depositional environment. Facies correlation was difficult in the fluvial system because the fluvial channels are relatively narrow (Fig. 2). Generally, the fluvial system is a progradational parasequence set where the number of parasequences varies laterally from two to three (Fig. 2).

The boundary between the fluvial system and shallow marine depositional environments is marked by a major erosive surface which is a possible
sequence boundary. The surface is the base of a channel that cut into the older fluvial sediments during a lowstand; it is interpreted as a distributary because it is at least 500 meters wide, which is much larger than the fluvial channels, and is filled with marine sediment (Fig. 2).

Relative sea level started to rise after the channel incision and abandonment. The distributary channel began to back-fill with mixed fluvial and tide deposits and, as transgression continued, it was converted into an estuary with muddier, finer, and more marine-influenced deposits.

Facies in the shallow marine succession can be correlated laterally, including the back-filled distributary channel (Fig. 2). The vertical succession consists of four progradational parasequences and three aggradational parasequences within highly retrogradational parasequence sets (Fig. 2). Each progradational cycle varies from 17 to 58 meters thick and consists of a back-filled distributary channel or tidal channel at the base followed by tidal flat or tidal bar sands with an overlying tidal mud flat or marginal marine coal (Fig. 2). Generally the progradational parasequences become thinner, muddier and more marine upward so that the whole succession is transgressive. The aggradational cycles vary in thickness from 13 to 17 meters and consist of tidal flat mud covered by marginal marine coal (Fig. 2).

4. Reservoir Potential

There are two facies with reservoir potential, fluvial channel sandstones and back-filled distributary channel sandstones. Fluvial channel sandstones fine upward from poorly sorted coarse to medium sand and often have pebbly and mud clast conglomeratic lag deposits at their base. They occur in lenticular beds that are up to 5 meters thick and less than 300 m wide based on channel width to sand thickness ratios (Gouw 2007). Consequently, they do not generate significant connected reservoir volume unless several sands are vertically stacked.

Back-filled distributary channel sandstones are cross-bedded, fining-upward coarse to fine sandstones with pebbly coal clasts and abundant flaser bedding. The amount of cross-bedding decreases upward while the amount of tidal influence increases upward. These sandstones are 8 to 21 meters thick, extend laterally for more than 500 meters in outcrop and could be up to 2 km wide using the modern Mahakam Delta as an analogue. There is no relationship between channel width and sandstone thickness because thickness depends only on the amount of back-filling before channel avulsion; therefore, thickness-width ratios are meaningless.

Fluvial channel sandstones and back-filled distributary channel sandstones are difficult to distinguish in the subsurface because both facies fine upward and are expected to generate similar log patterns (Fig. 3). In outcrop, the two types of sandstone occur within 40 meters of each other stratigraphically.
5. Conclusions

The sedimentology and stratigraphic architecture of the Grand Taman Sari Circuit outcrop indicates that:

a. It was deposited in fluvial and shallow marine depositional environments.

b. A basal fluvial succession is separated from the overlying transgressive shallow marine succession by a lowstand erosive surface that is the base of a distributary channel and could be a sequence boundary.

c. Fluvial channel sandstones and back-filled distributary channel sandstones have excellent reservoir potential but they have significantly different reservoir geometries, volumes and connectivity.

d. The two types of reservoir sandstone are difficult to distinguish in the subsurface because they generate similar log signatures.
Figure 2. Facies, stratigraphic successions and sand body correlations across the outcrop.
Figure 3. A) The stratigraphic succession in a fluvial channel sandstone and its predicted gamma ray log pattern, B) the stratigraphic succession and gamma ray log pattern of a back-filled distributary channel sandstone.
Acknowledgments

The author would like to thank Prof. Joseph Lambiase for his patient guidance and supervision during this research and for editing of this manuscript. The author wants to thank PTTEP and Chevron Thailand for financial support and Dr. Mike Bidgood and Dr. David Shaw for the biostratigraphic analyses.

References