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EVOLUTION OF TIDE-DOMINATED ESTUARINE FACIES SYSTEM IN THE OLIGOCENE OKHMINTAUNG FORMATION OF THE MYASAGAING-SHWEMAUNGZUN AREA, THE MINBU SUB-BASIN, CENTRAL MYANMAR

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Abstract

The data obtained from the Oligocene Okhmintaung Formation in the Myasagaing-Shwemaungzun Area, the Minbu Sub-Basin, central Myanmar are observed, and then used to establish the depositional processes and environments, and to reconstruct depositional model of the research area. A total of fourteen lithofacies are recognized, and grouped into four facies associations: tidal channel, tidal sand bar, tidal flat and transgressive shelf. Based on studies of the facies and facies associations, the lower part of the Okhmintaung Formation may mainly be deposited in tide-dominated estuarine system, which consist of a combination of tidal channel, tidal sand bar and tidal flat facies associations, and then followed by marine transgressive, resulting in deposition of alternating of transgressive shelf and tidal flat sequences in the upper part of the Okhmintaung Formation.

Keywords: Oligocene, Okhmintaung Formation, Minbu Sub-Basin, tide-dominated estuarine system

Introduction

The research area is situated in the southern part of the Minbu Sub-Basin, lying between north latitudes (19º35'05'' to 19º24') and east longitudes (95º10' to 95º03') and covering by one inch topographic maps of 85M/2 and 85M/3 (Figure 1A). It is located on the western bank of the Ayeyarwaddy River, and is bounded by Shwemaungzun Village of Sinbaungwe Township in the north and Myasagaing Village of Thayet Township in the south, Magway Region of Myanmar.

The mollassic clastic sedimentary rocks of the Oligocene-Miocene units of Pegu Group are mainly exposed in the research area (Theobald, 1973). The Pegu Group is distinctly marine portion in the south with the exception of the uppermost beds, while in the north it exhibits continental facies. The Pegu Group has been given much attention due to its presence of oil- bearing horizons. Accordingly, the Okhmintaung Formation of lower Pegu Group (Late Oligocene) has been selected for this research to recognize the detailed lithofacies types together with their distribution and to interpret the depositional environment through the lithofacies analysis (Figure 1B). This result allow to provide new insights on the purpose of a reconstructing depositional model of the Okhmintaung Formation, which help to understand the sedimentary characteristics of ancient depositional system and to estimate the prospective regions for hydrocarbon accumulations.

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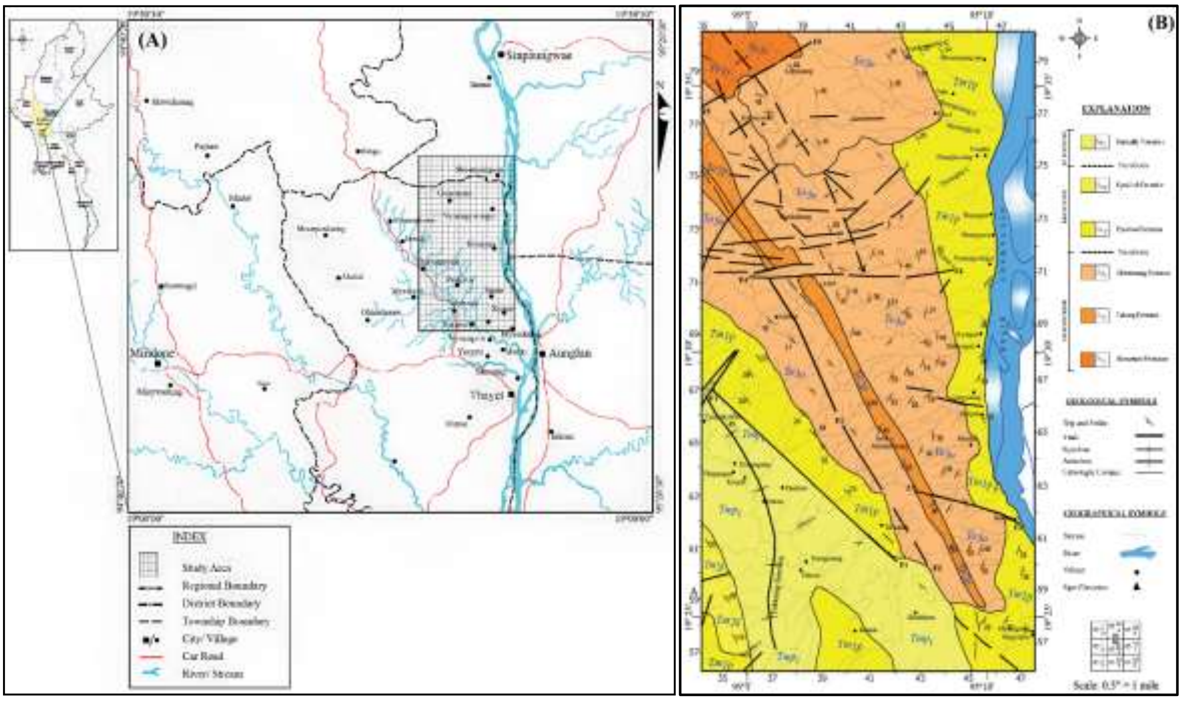

Figure 1 (A) Location map of the research area with the inset showing map of Myanmar and (B) Geological Map modified After M.O.G.E (1980).

Methods of Study

The traverses especially along the streams, rolling hills and road cuts are made by many measurements. While measuring along the traverses with tape measure, compass and GPS (Global Positioning System), one vertical section was profiled and logged in detail Kadin Chaung section in the western part of Sinthe Village. Recorded observations during field work include lithology, the degree of sorting of grains based on Compton (1962), grain size scale for sedimentary rocks based on the revised Udden-Wentworth scale (Blair and Mcpherson, 1999), sedimentary structures using the cross-bedding scale (Collinson, et al., 2006), trace and body fossil contents, and the mapping of discontinuity surfaces. The sedimentological information was graphically transformed into detailed textural graphic logs (Tucker, 1996). A modified lithofacies classification scheme from (Miall, 1977; 1978; 1985; 2006) was used in this study.

Facies Association and Interpretation

In the research area, fourteen lithofacies can be recognized for the Okhmintaung Formation (Table 1), and can be grouped into four faices associations: (1) tidal channel, (2) tidal sand bar, (3) tidal flat and (4) transgressive shelf.

Facies Association 1: Tidal Channel

In the inner part of the estuary where the river channel is influenced by tidal processes, the low-gradient channel commonly adopts a meandering form (Dalrymple et al., 1978). The outer part of a tide-dominated estuary is the zone of strongest tidal currents, which transport and deposit both fluvially derived sediment and material brought from the sea. In supratidal zone, the currents will be strong enough to cause local scouring and to move both sand and gravel. Bioclastic debris of facies A is common among the gravelly detritus deposited as a lag on the channel floor (Reinson, 1992).

The tidal effects mean that there are considerable fluctuations in the strength of the flow during different stages of the tidal cycle: when a strong ebb tide and the river act together, the combined current may transport sand, but a strong flood tide may completely counteract the river flow, resulting in standing water, which allows deposition from suspension. The deposits in the point bar consist of more than one grain size, in this case alternating layers of sand and mud (Reineck and Singh, 1980). This style of point-bar stratification has been called 'inclined heterolithic stratification' (IHS) (Thomas et al., 1987) and named as facies L in this research. Trough cross-bedding (facies G) and ripple mark (facies D) in sandstones may serve as channel deposits.

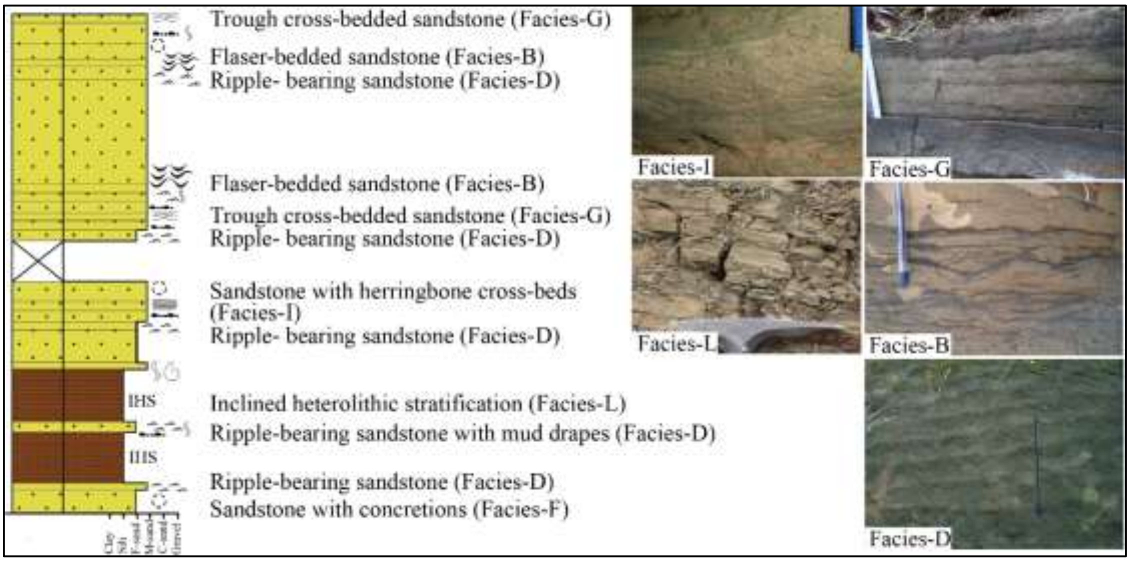

Figure 2 Idealized sequence of tidal channel facies association and outcrop photographs of trough cross-bedded sandstone (Facies-G), flaser-bedded sandstone (Facies-B), ripple-bearing sandstone (Facies-D), sandstone with herringbone cross-beds (Facies-I) and inclined heterolithic stratification (Facies-L).

Table 1 Lithofacies scheme for the Okhmintaung Formation exposed in the Myasagaing-Shwemaungzun area

Lithofacies Code		Lithofacies Name	Grain size	Bed Thickness (cm)	Sedimentary Structure	Boundary	Interpretation
A		Intraformational conglomerate	Pebble	30	Lack of internal structure	Sharp	Marginal marine to estuarine
B		Medium bedded sandstone with flaser bedding	Medium sand	45	Flaser bedding	Sharp	Delta, tidal flat
C		Planar-cross bedded sandstone	Medium sand	53	Planar-type cross bedding	Sharp, erosional	Tidal sandbar, channel bar
D		Ripple- bearing sandstone	Medium sand	40	Wave ripple	Sharp	Offshore, channel-shoal, transition zone in delta, tidal flat, estuarine
E		Fossiliferous sandstone	Fine-medium sand	18	Lack of internal structure	Sharp, gradational	Lower shore face deposit

Lithofacies Code		**Lithofacies Name**	**Grain size**	**Bed Thickness (cm)**	**Sedimentary Structure**	**Boundary**	**Interpretation**
F		Sandstone with spherical shaped concretion	Fine-medium sand	197	Sandstone concretion (6 to 10cm in diameter)	Sharp	Beach ridge develops on marshy regions
G		Trough type cross-bedded sandstone	Fine-medium sand	10	Small scale cross stratification	Gradational	Aeolian deposits, fluvial, tidal fat
H		Sandstone with mud clasts	Fine sand	215	Lack of internal structure	Sharp, gradational	Sand flat, upper flow regime
I		Sandstone with herring- bone cross bedding	Fine sand	70	Herring-bone cross bedding	Gradational	Tidal channel
J		Medium bedded sandstone with wavy bedding	Fine sand	649	Wavy bedding	Sharp, gradational	Shore face, tidal flat, tidal channel and delta
K		Thick bedded sandstone with lenticular bedding	Mud, fine sand	195	Lenticular bedding	Sharp	Subtidal-intertidal zone, tidal flat
L	IHS	Inclined heterolithic stratification (IHS)	Mud, silt, fine sand	720	IHS	Sharp, gradational	Deltaic channels, estuarine channel bar in mixed tidal-fiuvial channel
M		Sand-shale interbed	Shale, fine-medium sand	1177	Sandstone & shale interbed	Gradational	Tidal flat
N		Concretionary mudstone	Mud	120	Concretionary mudstone	Gradational	Inner to mid shelf

Facies Association 2: Tidal Sand Bar

Tidal sand bar facies association make up almost entirely of sandstone with planar-cross bedded (facies C), mud drapes (faceis H) and inclined heterlithic stratification (IHS) (facies L) and grade upward into horizontally laminated sandstone with a minor percentage of siltstone and shale. Bed-bases are sharp with scours and in some places, load structures. This facies association mostly occupy the middle part of the Okhmintaung Formation and is directly associated with tidal flat and tidal channel facies associations.

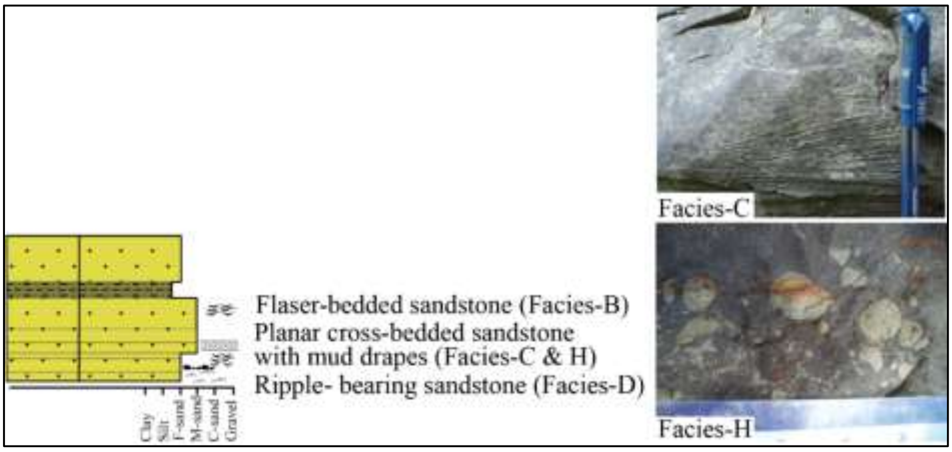

Figure 3 Idealized sequence of tidal sand bar facies association and outcrop photographs of planar cross-bedded sandstone (Facies-C) and mud clasts in sandstone (Facies-H).

Facies Association 3: Tidal Flat

Tidal flats develop along the gently dipping sea coasts with marked tidal rhythms, where enough sediment is available and strong wave action is not present (Reineck and Singh, 1980). The main part of the tidal flat is located between intertidal zones. Primary sedimentary structures for tidal flat deposits include lenticular (facies K), wavy (facies J) and flaser bedding (facies B). This facies association is divided into three main parts: (1) sand flat, (2) mixed flat and (3) mud flat. Planar cross-bedded sandstone (facies C), sandstone with herring-bone cross bedding (facies I), medium bedded sandstone with wavy bedding (facies J) and thick bedded sandstone with lenticular bedding (facies K) may be sand flat deposits. Medium bedded sandstone with flaser and wavy beddings (facies B and J), thick bedded sandstone with lenticular bedding (facies K), and sand-shale interbed (facies M) may be assigned as the mixed flat deposit. Massive or crudely bedded mudstone with concretionary may be assigned to be deposited in the mud flat. Tidal flat facies associations are generally topped by transgressive shelf facies association, and underlain by tidal channel facies association.

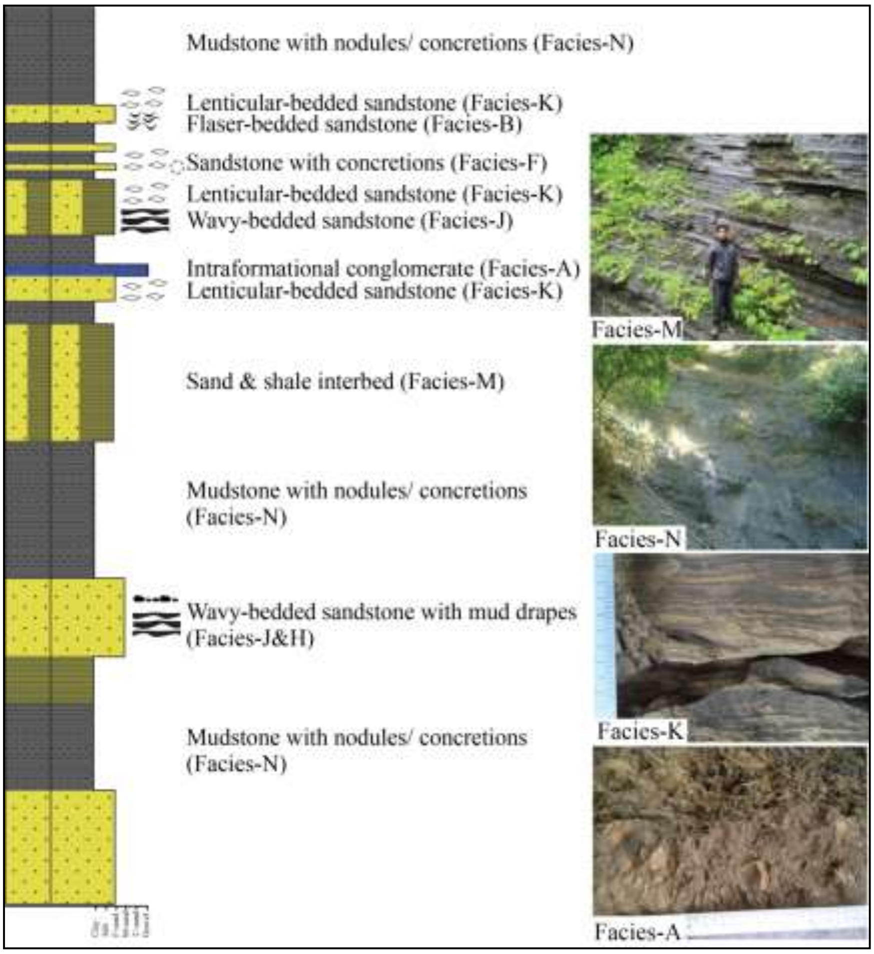

Figure 4 Idealized sequence of tidal flat facies association and outcrop photographs of sand & shale interbed (Facies-M), mudstone with nodules/ concretions (Facies-N), lenticular-bedded sandstone (Facies-K) and intraformational conglomerate (Facies-A).

Facies Association 4: Transgressive Shelf

The continental shelf is submerged under an area from the shore line down, to about 200m, where the gentle slope of the continental shelf changes into the steep slopes of the continental slope (Reineck and Singh, 1980). Mud deposits can be found on the near shore shelf with small amount of coarse silt layers. The degree of bioturbation of shelf mud can be highly variable and bioturbation structures are abundant. A thin shell layer sometimes is present, pointing to intermittent erosion, that lead to concentration of shells as lag. Sediments are homogenous-looking clay, shelly clay, and shell layers. The major source of shell mud sediments is the suspension load of rivers, which by passes the coastal region and is deposited on the shelf (Reineck and Singh, 1980).

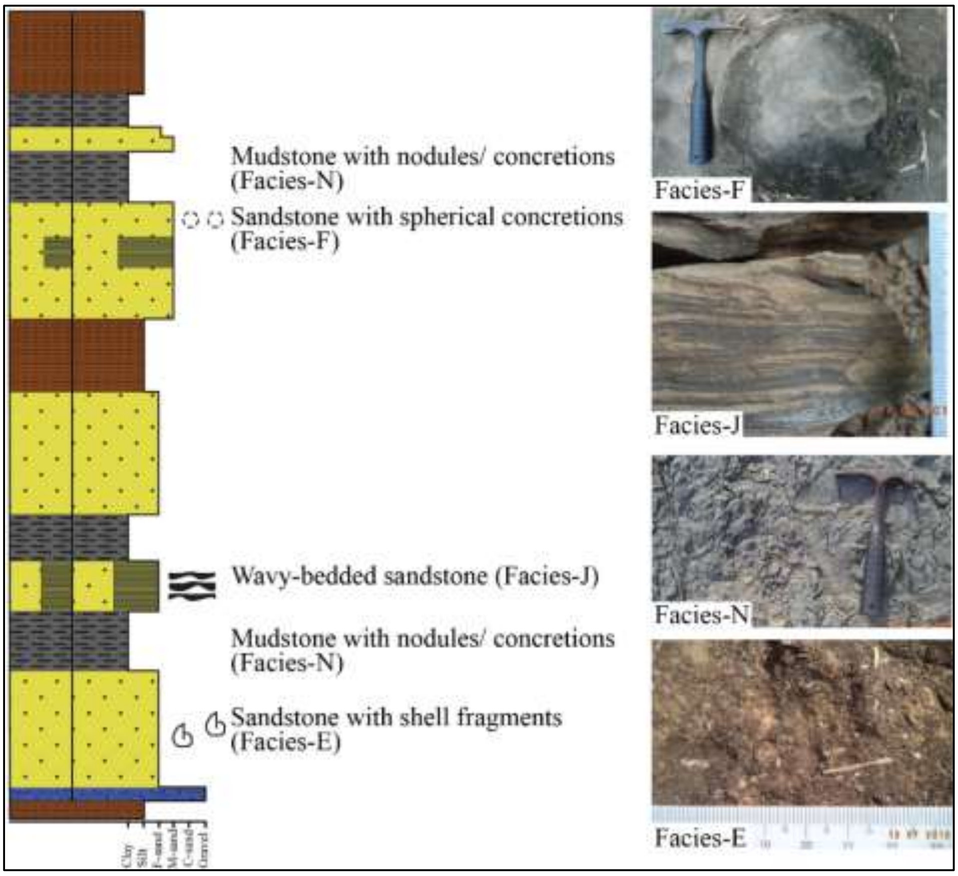

Figure 5 Idealized sequence of transgressive shelf facies association and outcrop photographs of sandstone with concretions (Facies-F), sandstone with wavy bedding (Facies-J), mudstone with nodules/ concretions (Facies-N) and sandstone with shell fragments (Facies-E).

The combination of reddish brown to greenish brown colored, fine grained sandstones with shell fragments and burrows (facies E) and bluish grey colored, concretionary mudstone (Facies N) represent into transgressive shelf marine facies association. This facies association is associated with tidal-flat deposits of estuarine system.

Discussion of the Depositional System

The Tertiary sediments recorded a history of infilling of the forearc basin (Minbu Sub-Basin) by marine sediments from the south and non- marine deposits from the north. The process was interrupted by marine transgressions and regressions, resulting in intertonguing of continental and marine units (Stamp, 1922; Chhibber, 1934). Depositional environment of the research area may be interpreted on the basis of the textures, sedimentary structures, fossils, and lithologic associations of sedimentary rocks on the scale of an outcrop.

Evidence for tidal conditions include mud drapes (facies H), and herringbone cross-stratification (facies I). The mud drapes form as the current slows down when the tide turns.

Subtidal zone make up of channel and sand bar sediments. Bioturbation is very weak, as the rate of sedimentation is very high in the tidal channel. The tidal channel show mud drapes and inclined heterlithic stratification. The channel bottoms of the larger tidal channels are mostly sandy, enriched in shells (faceis E). Evidence for tidal bar conditions in sand beds include planar-cross bedded (facies C), mud drapes (faceis H), and herringbone cross-stratification (facies I). Herringbone cross-bedding is relatively uncommon because the ebb and flood tidal flows tend to follow different pathways, with the flood tide going up one side of the estuary and the ebb tide following a different route down the other side.

The tidal flat is located in intertidal zone where sediments have been deposited by tides or rivers. The primary sedimentary structures which were formed under tide flat condition include mega-ripple (faceis D), small amount of herringbone cross bedding (faceis I), small scale cross bedding (faceis G) on the sand flat, flaser (faceis B), wavy (faceis J), and lenticular beddings (faceis K) on the mixed flat. Mud and silt layers with concretion (faceis N) rich in organic material are typically in muddy tidal flat deposits.

Transgressive shelf succession is typically mudstone, often organic-rich with thin, wave-rippled sand beds (Boggs 2006). Sandstone with shells or shell fragments (facies E) and bioturbated muds (facies N) indicate the influence of shallow marine clastic system. Summing up the above factors, lower part of the Okhmintaung Formation may be deposited in the tide-dominated estuarine environment which consist of tidal channels, tidal sand bars, and tidal flats, and followed by deposition of transgressive shelf system in the upper part of the formation.

Conclusion

Fourteen distinguishable lithofacies frameworks can be established, and can be grouped into four facies associations, comprising tidal channel, tidal sand bar, tidal flat and transgressive shelf. The facies architectures reveal that the evolution of the Okhmintaung Formation is mainly related to the Oligocene sea-level rise. At the early depositional stage of the Oligocene transgression, tide-dominated estuarine system occurs as the basal units at the lower part of the Okhmintaung Formation. At the late depositional stage of the Okhmintaung Formation, significant marine transgression takes places and it shifts in facies depositions from tide dominated estuarine to a transgressive shelf sequences in the upper Okhmintaung Formation. As a result of the factors mentioned above, the Oligocene Okhmintaung Formation may have deposited in tide-dominated transgressive estuarine system (Figure 6).

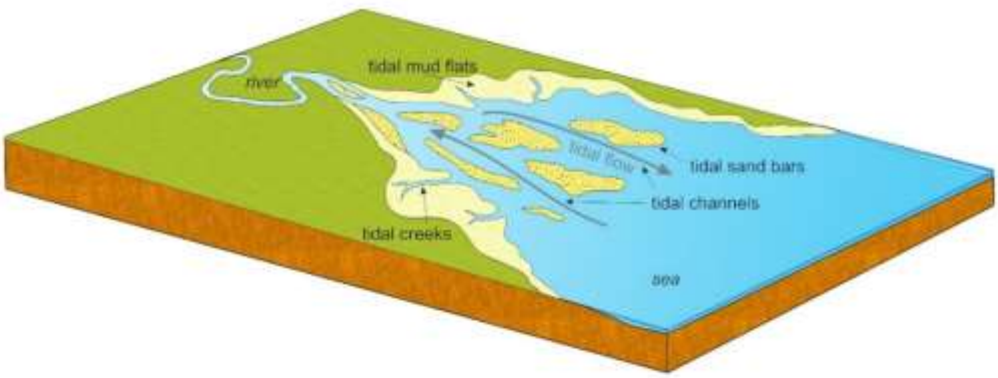

Figure 6 Depositional model of the research area showing tide-dominated estuarine facies system (Nichols, 2009).

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