Modern Analogue of Shaly Sand Reservoir on Coastal Plain in Selat Baru, Bengkalis Island, Indonesia

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Abstract. Coastal environment is one of main reservoir depositional system in the oil industry and becomes the main challenges in defining its characteristic, especially in lateral correlation. Research conducted in Bengkalis Island which has a unique characteristic of coastal depositional environment that affected by a tidal system related to modern analogue for reservoir characterization. The method used for this research is analysing lithofacies from drilled core data, surface sampling, and lateral measurement from foreshore to the tidal limit. It is confirmed from core data that research area consists of sand, shale, and peat with lamination, cross laminations sedimentary structure and also filled with organism activity, which clustered into eight lithofacies. By integrating the core data with surface sampling and lateral measurement, it is interpreted that facies is changing only in near distance (about 30 – 40 m) with sloping 1 – 2 degrees in the surface, so by defining the same characteristic on lithofacies, correlation can clearly define on a shaly sand reservoir in the tidal coastal environment.

1. Introduction
Selat Baru is a small area that located in the northern coast of Bengkalis Island, Riau, Indonesia and contiguously to Malacca Strait (Figure 1). The Malacca Strait is located between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, it is linked with the Strait of Singapore at the south-east end [1,2]. The study area was found to have brackish water in its river flow owing to a certain amount of salt water mixing [3,4]. The study was initiated from the result of water quality analysis in the western area of Bantan Tua, Jangkang and Deluk village which adjacent directly to Selat Baru Village.

The organic matter preserved in marine sediments contains varying contributions of terrestrial and marine source inputs, an issue that relevant to an area along the coastal margins where most carbon burial occurs [5]. Terrestrial organic matter deposited in marine sediments might then be expected to undergo less efficient re-mineralization and therefore be preferentially buried [6]. Large amounts of terrestrial organic carbon are annually transported from the continents to the oceans mainly by fluvial
transport or, in lower amounts, by aeolian dust [7]. Understanding the fate of Terrestrial Organic Matter (TOM) in marine sediment is important for some reasons. In part, this interest stems from the observation that marine organic matter is broadly considered to be more reactive than terrestrial organic matter [6].

Stratigraphy of the study area composed of rocks that include surface deposits which are Young Superficial Deposit (Qh), and Older Superficial Deposit (Qp) [8]. Young Superficial Deposit consists of clays, silts, clean gravel, vegetation rafts, peat swamps and Older Superficial Deposits consist of clays, silts, clayey gravels, vegetation rafts [9].

The Northern Coast of Bengkalis Island, which is located on the estuary, have a thicker TOM compared to the beach that located further. The Selat Baru Beach is relatively cleaner because it is not in the estuary part, but the number of mangrove forests around it becomes a source of TOM that was carried to the coast. This study aims to determine the characteristics of coastal sediments and their changes vertically and laterally, it can be used as an analogue reservoir in the coastal environment which is influenced by the presence of high terrestrial organic matters.

Figure 1. Study Area in Selat Baru Area, Bengkalis Island - Indonesia

2. Methodology

The method used consist of several steps and measurements [10]. There were field survey and laboratory analysis. Field survey were conduct to specify the drilling position and lateral measure section on Selat Baru Beach. Drilling has been carried out at 3 well locations using hand auger on 2 metres depth. The lateral cross section was conducted from the sea tide limit up to lowest position of the sea water [2] and the samples of sediment were taken every 10m. Availability of the data in this study can be seen in Table 1.

Laboratory analysis is carried out by performed sieve analysis (the sieve size in 2.38 cm, 1.19 cm, 0.6 cm, 0.297 cm, 0.149 cm, 0.074 cm, 0.04 cm, and 0.02 cm). This analysis has to be done to obtain the dominant of grain size, sorting, skewness, and kurtosis of the core drilled and lateral measure section samples.
### Table 1. Availability of research data

| Data | Name of Data | Location          | Coordinate       | Depth | Length |
|------|--------------|-------------------|------------------|-------|--------|
|      |              |                   | Long             | Lat   |        |
| Core | #SB 1        | Selat Baru Beach  | 01°33’37.00”    | 102°14’45.00” | 300 cm |
|      | #SB 2        | Selat Baru Beach  | 01°33’44.00”    | 102°14’44.00” | 200 cm |
|      | #SB 3        | Selat Baru Beach  | 01°33’47.00”    | 102°14’37.00” | 200 cm |

| Measure Section | Name of Data | Location          | Coordinate       | Length |
|-----------------|--------------|-------------------|------------------|--------|
| #SNB 1          | Selat Baru Beach | 01°33’47.00”    | 102°14’37.00” | - | 185 m |
| #SNB 2          | Selat Baru Beach | 01°34’08.6”    | 102°11’12” | - | 180 m |
| #SNB 3          | Selat Baru Beach | 01°34’07.45”   | 102°11’12.34” | - | 210 m |

3. Result and Discussion

3.1 Granulometry Analysis

Granulometry analysis has been performed to trenching data with 30 cm depth at line measure section. The grain size distribution of sediment in Selat Baru Beach is dominated by medium sand, good to excellent sorting and spreading towards finer granules with very platykurtic kurtosis value (Table 2).

### Table 2. Summary of Granulometry Analysis

| Data | Name of Data | Location          | Coordinate       | Granulometry Analysis |
|------|--------------|-------------------|------------------|-----------------------|
|      |              |                   | Long             | Lat   | Mean | Standard Deviation | Skewness | Kurtosis |
|      |              |                   | 0 - 2.7 m        | 0.271 | 0.423 | 0.334 | 0.112 |
|      |              |                   | 3.7 - 4 m        | 0.212 | 0.218 | 0.007 | 0.009 |
|      |              |                   | 33.3 - 34 m      | 0.241 | 0.404 | 0.48  | 0.07  |
|      |              |                   | 56 - 57 m        | 0.132 | 0.222 | 0.145 | 0.025 |
| #SNB 1 | Selat Baru Beach | 01°33’47.00”    | 102°14’37.00”   | 0 - 2.7 m | 0.286 | 0.485 | 0.534 | 0.112 |
| #SNB 2 | Selat Baru Beach | 01°33’47.00”    | 102°14’37.00”   | 67 - 70 m | 0.201 | 0.279 | 0.128 | 0.0203 |

3.2 Core Data Analysis

Sediment of core data from 3 locations had been analysed, the result shows several types of sediment such as mud, silt and fine sand (Figure 2). Most of these sediment contain Terrestrial Organic Matters (TOM) with varying percentage. In addition, several sediment structures were found in core data. For example: ripple mark, cross lamination, flaser, lenticular, and burrow. Based on core data analysis, characteristic of sediment obtained as followed:

1. Finesand with burrow
2. Finesand with Terrestrial Organic Matter (TOM)
3. Finesand with ripple mark and fine size of TOM
4. Mud with fine size of TOM
5. Laminated mud with lenses of TOM
6. Cross laminated Silt to Mud with TOM
7. Cross laminated Silt to Mud with Burrow
3.3 Lateral Measured Section Analysis
Based on the description of measured cross section by observing the physical character in the field, several characteristics of the sediment structure were found. There were massive, ripple mark, burrow, lenticular and flaser. Fine sand sediment with fine sized organic material and ripple mark with a slope angle of 40° and some location have low angle (< 20°). The types of ripple mark are symmetrical, transverse ripple and barchan-shaped becoming transverse ripple.
Ripples can be generated by waves, currents or both, very small waves and weak currents are unable to move the sand, so that it cannot create or modify the ripples. The orientation of the ripples is aligned with the forcing waves or current, and changes (with a time-lag) as the forcing direction changes, ripples can be flattened by biological action in a few hours. The ripple also will be damaged by very large waves or strong currents wash out ripples, when the strengths of the waves and currents diminish.

Coastal sediment in the research area dominated by well sorting - fine sand. The influenced of land sediment material such as Terrestrial Organic Matter (TOM) given the specific characteristic to the coastal sediment of the research area. The coastline that located closed to estuary would have thicker TOM deposit compared to the beach that far from the tidal mouth. Estuary brought the material from the land to the ocean with various percentage. Selat Baru beach located away from the estuary, therefore the TOM deposit was not dominant in this area. However, high erosion rate in the coastal area, especially in the mangrove conservation area, would bring the mangrove material to the shoreline.

Sedimentary structures that developed in this coastal area were ripple mark, cross lamination, bioturbation, flaser and lenticular. Characteristic of coastal sediment could be used as an analogue in determination of depositional environment, notably coastal and transitional environment that effected by the ocean and occurrence of inland TOM. Ripple mark formation had been influenced by the grain size of sediment, current and waves.

4. Conclusion
Selat Baru beach has several sedimentary facies that dominated by well-very well sorting fine sand (0.125-0.25 cm), TOM content, ripple mark, cross lamination, bioturbation (i.e. burrow, track and trail), flaser and lenticular. In addition, clay and silt deposit could be found. The sedimentary deposit changed vertically and laterally. There are seven sediment facies such as fine sand with burrow; fine sand with terrestrial organic matter (TOM); fine sand with ripple mark and fine size of TOM; mud with fine size of TOM; laminated mud with lenses of TOM; cross laminated silt to mud with TOM and cross laminated silt to mud with burrow.

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