Facies and Architectural Element Analysis of Braided Fluvial Succession: The Tertiary Sawah tambang Sandstone, Sawahlunto, Indonesia

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Abstract. The Sawahtambang Sandstone Formation of Sawahlunto, Indonesia has hitherto never been studied in detail to ascertain its depositional processes and its palaeoenvironment. The Sawahtambang Sandstone has more than 394 m thickness which consists of conglomeratic sandstone, sandstone, and clay-silt intercalation within which six lithofacies types (St, Sp, Sh, Ss, Fl, and Fm) appear creating iterated fining upward sequence. Herewith, this paper aims to replenish the avantgarde sedimentological interpretation of the Sawahtambang Sandstone in the intermontane basin of Indonesia based on outcrops along the Trans-Sumatra Highway. The study is attained through facies identification based on stratigraphic measuring section or outcrop profile, studio analysis consists of log analysis and superposition reconstruction, and architectural element delineation according to facies association. Structures in clay-silt facies consist of lamination and fissile whereas in the sand grained include planar and trough cross-bedding, planar lamination and granule lag, which depicts a lower-flow-regime sand channel. The architectural elements that made from facies association are identified into five distinct elements (multi-storey channel, single storey channels, sand bedforms, laminated sand sheet, and floodplain fines), which present a fluvial environment. The relation of the architectural elements demonstrates that the Sawahtambang Sandstone uphold a record of the braided river system that flowed from southwest to northeast in the southwestern part of Ombilin Basin. The dominance of coarse-grained (channel and sandy bedform) element over clay-silt grained (laminated sand sheet and floodplain fines) element and the extensive appearance of thick amalgamated channel elements reinforce the interpretation of a low-sinuous braided fluvial system in which the stacking pattern shows the channel bodies accumulated both lateral via lateral accretion of point bar and via vertical amalgamated streams.

1. Introduction

Geographically, The study interest area is located in Sawahlunto City, West Sumatra. The research area is located in Ombilin Basin, an intermontane basin in the Sumatra Fault System (SFS). In general, the rocks exposed in the study area were amalgamated Sawahtambang Sandstone Formation with varying grain sizes and showed the appearance of palaeochannel from the braided river system. The Sawahtambang Sandstone Formation is also imperative in basin analysis study for further understanding the yet undiscovered petroleum play in Ombilin Basin. The unit is actively mined for construction industry materials. Although the regional geology of the Ombilin Basin area is relatively well documented [1], currently, there is a gap in our knowledge of the characteristic of the
Sawahtambang Sandstone Formation over the internal configuration of the facies, and architectural elements.

Research on lithofacies and architectural elements in fluvial sediment in Indonesia is scarce. In the same hand, a comprehensive study of facies association of Sawahtambang Formation has not been done before. This is because the fluvial deposits in Indonesia are mostly located under the earth surface or not exposed well on the surface. So far, facies studies commonly done in Indonesia are in marine or deep marine deposits. Therefore, a more massive study of fluvial flux facies in Indonesia is needed to understand the fluvial characteristics, as well as to preserve existing fluvial outcrops for future study. In addition, the largest oil and gas reserves in Indonesia are located in sandstone reservoirs of fluvial sediment.

In line with the importance of lithofacies research, research on architectural elements is also essential. Determination of architectural elements is shown to identify facies associations at research sites and useful for understanding the geometry of the sedimentation process. The study of architectural elements on fluvial deposits based on surface data or surface sedimentary rock outcrops aims to provide an overview of ancient river flow patterns and sandstone compartments that have the potential to be hydrocarbon reservoirs.

![Figure 1. Simplified geological map of the south-western part of the Ombilin Basin, showing where the nine sedimentary logs discussed in this paper are located.](image)

### 2. Data and Method

In this study, the authors use the integration method of field research data and literature and previous research studies. Previous research refers to [2–4]. Furthermore, field data was collected at continuous sedimentary rock outcrop of the Sawahtambang Formation sandstone deposit in the study area. The outcrop was examined by performing a vertical profile depiction showing facies aspect and flow analysis for later interpretation of the sedimentation process and the deposition environment as well as the geometry of architectural elements.

In conducting this study, nine (9) observation sites were selected in the study area, where the outcrop was obtained with good vertical and lateral increments. The outcrops are divided into 3 segments based on the region's name: Cold Water Bukit Segment, Segment Muaro Kalabab and Kepala Koto Segment (Figure.1).
3. Result and Discussion
Sawahtambang Formation consists of dominated sandstone facies. The result of the research are the characteristic of the variety of lithofacies and architectural element in Sawahtambang Formation.

3.1. Lithofacies of Sawahtambang Formation
The Sawahtambang Sandstone Formation in the purpose of sedimentology facies study can be divided into six identified lithofacies which the brief description and interpretation are provided in (Table. 1). In order to detect the sedimentation direction, palaecurrents data are measured. Mean palaecurrent direction of the Sawahtambang Sandstone Formation at Sawahlunto City is the northeast.

The Sawahtambang Sandstone Formation is identified as a recycled orogen provenance. The lithofacies nomenclature is utilizing \[2–4\] which is still relevant until the present day \[5\][6][7][8][9].

Based on the field observation in the research area, the variety of lithofacies in the research area is divided into three segments, which are (1) Bukit Air Dingin (BAD) Segment, (2) Muaro Kalaban (MKB) Segment, and (3) Kepala Koto (KK) Segment.

**Table 1.** Identified lithofacies for the Sawahtambang Sandstone Formation at Sawahlunto, Indonesia.

| Facies | Description | Sedimentary Structure | Interpretation |
|--------|-------------|-----------------------|----------------|
| St     | Sand, medium to v. Coarse, poorly to well sorted, may be quartz granule in channel base, 50 to 3 m thick sets. | Solitary (theta) or grouped (pi) trough crossbeds (Figure. 2A & B) | Sandy Dunes (lower flow regime) |
| Sp     | Sand, medium to v. Coarse, poorly to well sorted, may be quartz granule in channel base, 50 cm to 2 m thick sets. | Solitary (alpha) or grouped (omikron) planar crossbeds (Figure. 2C) | Linguoid, transverse bars, sand waves (lower flow regime) |
| Sh     | Sand, v. Fine to medium, moderately to well sorted 10 to 60 cm thick beds. | Horizontal lamination (Figure. 2E) | Bar-top deposit and sand sheets |
| Sr     | Sand, very fine to medium grained | Ripple cross-lamination (Figure. 2D) | Migration of rippleforms |
| Ss     | Sand, fine to coarse, may be a granule, 10 to 30 cm thick beds. | Broad, shallow scour including eta crossstratification (Figure. 2F) | Scour fills, erosional surface, channel lag deposits |
| Fl     | Interlayered Very Fine Sand, silt, with grey or carbonaceous mud or shale 5 cm to 7 m thick beds. | Fine lamination, very small ripples, iron oxide (Figure. 2G) | Overbank or waning flood deposits, laminated sand sheet |
| Fm     | Grey Mud, silt, 20 cm to 4 m thick beds. | Massive, desiccation cracks, iron oxide (Fig. 2H) | Overbank or drape deposits, laminated sand sheet |

3.2. Architectural Element of Sawahtambang Formation
This analysis is conducted to find out the variation of architectural elements by characterizing the logs vertically. The analysis was performed on 9 (nine) selected observation locations with good physical aspects which grouped into three segments.

Based on the classification, there are 5 architectural elements in the research area are *Multistorey, Amalgamated Channel; Single Storey, Fluvial Channel; Sand Bedform, Laminated sand sheet; and Floodplain* (Table. 2). In addition, there is also a faciesassociation formed based on field data to provide an overview of facies associations that form the architectural elements in the Sawahtambang Formation in the research area. It can be seen that the results of the analysis of architectural elements illustrate that the research area in the southeast and northwest partsare dominated by *overbank fines* elements while in the center is dominated by elements *sandy bedform* and *channel*. It is interpreted that the *active channel* is in the middle of the study area while the southeast and northwest are *overbank fines*. 


**Table 2.** Architectural Element classification based on Miall (1985, 2014) and Scherer (2015) which identified in Sawah tambang Formation in Muaro Kalaban, Sawahlunto, Indonesia.
4. Conclusions
Sawahtambang Sandstone Formation in the research area was divided into three segments which are Air Dingin Hill Segment, Muaro Kalaban Segment, and Kepala Koto Segment. The Sawahtambang Formation records deposition within a fluvial braided river system accumulated in intramontane basin deposited during the post-rift phase in Neogene. This stratigraphic unit encompasses six main lithofacies ascribe to; (i) sand trough cross-beds (St), (ii) sand planar cross-beds (Sp), (iii) sand horizontal lamination (Sh), (iv) sand scour and fill (Ss), (v) fine-grained horizontal lamination (Fl), (vi) fine-grained massive (Fm).

Five elements architecture were identified, which are (i) multistorey, amalgamated fluvial channel sand bodies, (ii) single-storey fluvial channel sand bodies, (iii) sandy bedforms, (iv) laminated sand sheet and, (v) floodplain. The Sawahtambang Braided Fluvial River succession was deposited directed to North-East and the fine-grained floodplain was developed towards North-Western. Bukit Air Dingin Segment was deposited in a floodplain or overbank deposits dominated with laminated sandstone lenses and minor river channel. Muaro Kalaban Segment was deposited in the active core channel or Multi-storey, amalgamated channel bars (Scherer, 2015) with a minor fine-grained appearance. Whereas Kepala Koto Segment was sedimentsed in a Multi-storey, amalgamated channel bars and were overlaid by thick fine-grained floodplain deposits. The core of channel deposits is located in the center part of the research area which is identified as a potential hydrocarbon reservoir. The core segment is consist of the amalgamated channel and sandy bedform deposits with very thin overbank fines element.

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