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Facies and architectural analysis of Paleogene fluvial deposits of the measured section of Rambangnia and Air Napalan Rivers in the Palembang Sub-basin

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Abstract

Paleogene fluvial deposits have an important problem as pre-rift deposits, which occur before or at the same time as the formation of the basin. The research results on facies analysis and interpretation of the depositional environment of Paleogene deposits located in the Garba Hills will later explain and describe the history of the formation and stratigraphic evolution of sedimentary rocks in the South Sumatra Basin, reflected in the lithological and facies characteristics. The facies analysis was carried out on a stratigraphic cross-section with a thickness of ± 107.37 meters and ± 11.06 meters on the measurement path of the Rambangnia River and Air Napalan River, which are located in the Ogan Komering Ulu area, South Sumatra. Seven lithofacies developed on two measured paths are matrix-supported graded gravel (Gmg), gravel matrix supported Massive (Gmm), through cross-bedded (St), massive sandstone (Sm), horizontally bedded sandstones (Sh), parallel laminated siltstone and claystone (F1), massive siltstones and mudstones (Fsm). Asosiasi fasies didapatkan berupa Sedimentary Gravity Flow (SG), Gravel Bars (GB), Sandy Bedforms (SB), channel (CH), Overbank fine (FF). The interpretation of the depositional environment shows a fluvial environment, the type of braided river with a gravel braided river model with sedimentary gravity flows.

1. Introduction

1.1 Background

Geographically, the research location is in Bungincampang Village, Simpang District, South Ogan Komering Ulu Regency, South Sumatra Province (Figure 1). The location is in the Palembang Sub-basin, which is part of the South Sumatra Basin. In general, the kind of rock that becomes the focus of this research is the Kikim Formation, the oldest rock in the South Sumatra Basin [1] The Kikim Formation has also been widely studied because it is one of the formations that have an important role in the petroleum system in the South Sumatra Basin.

Detailed research focusing on facies analysis, sedimentation processes, and depositional environment interpretation have not been carried out much. This fact is because the Paleogene deposits of the basin are dominated by land deposits, making it difficult to determine the age, distribution, and source of each lithological unit. Studying facies in more detail will undoubtedly provide an overview of the processes that occurred when the rocks were deposited in the basin.

This research is concerned with the stratigraphy (based on sedimentological analysis) of Paleogene deposits from measured surface trajectories. The study results will provide an explanation and description of the depositional environmental conditions that occurred during the formation of the sediment as reflected in the lithological and facies characteristics.

1.2 Regional Geology

The South Sumatra Basin is located to the east of the Bukit Barisan, extending to the northwest-southeast direction, including a back-arc basin, bounded by the Bukit Barisan Mountains in the southwest and the pre-tertiary Sunda Shelf in the northeast [2] The South Sumatra Basin is a large basin consisting of several sub-basins. The sub-basins are Jambi Sub-basin (North Palembang), Central

Palembang Sub-basin, and South Palembang Sub-basin (Palembang Complex). The research area is included in the South Palembang Sub-basin.

According to [1] and [3] the stratigraphy of the South Sumatra Basin is sequential from the oldest to the youngest rocks, namely the basement, Garba, Kikim, and Lahat Formation in the terrestrial environment above the Mesozoic basement. In the transgression phase, in the marine environment, rock formations were deposited (sequentially from the oldest), namely Talang Akar Formation, and Batu Raja, and ended with Gumai Formation in a deep marine environment. Then, the regression phase begins with the deposition of the Air Benakat Formation in a shallow marine environment, the Muara Enim Formation in a transitional environment, and ends with the Kasai Formation (Figure 2) in a terrestrial environment.

There are 3 tectonic phases that play a role in the development of Sumatra Island and the South Sumatra Basin, according to [4] The compression phase from the Early Jurassic to the Cretaceous (Paleozoic-Mesozoic deposits were metamorphosed, folded, and fractured into structural lumps and formed the basic pattern of basin structures). The extensional phase occurred in the Late Cretaceous to Early Tertiary, resulting in N-S and NW-SE's tectonism. Sedimentation filled the basin along with volcanic activity, combined with the results of Paleozoic and Mesozoic orogenesis and weathering of pre-tertiary rocks. The compression phase in the Plio-Pleistocene resulted in the Bukit Barisan Mountains being uplifted, resulting in a Sumatran horizontal fault that developed along the Bukit Barisan Mountains. The dominant structural appearance is a northwest-southeast trending structure due to the Plio-Pleistocene orogenic process (Figure 3)

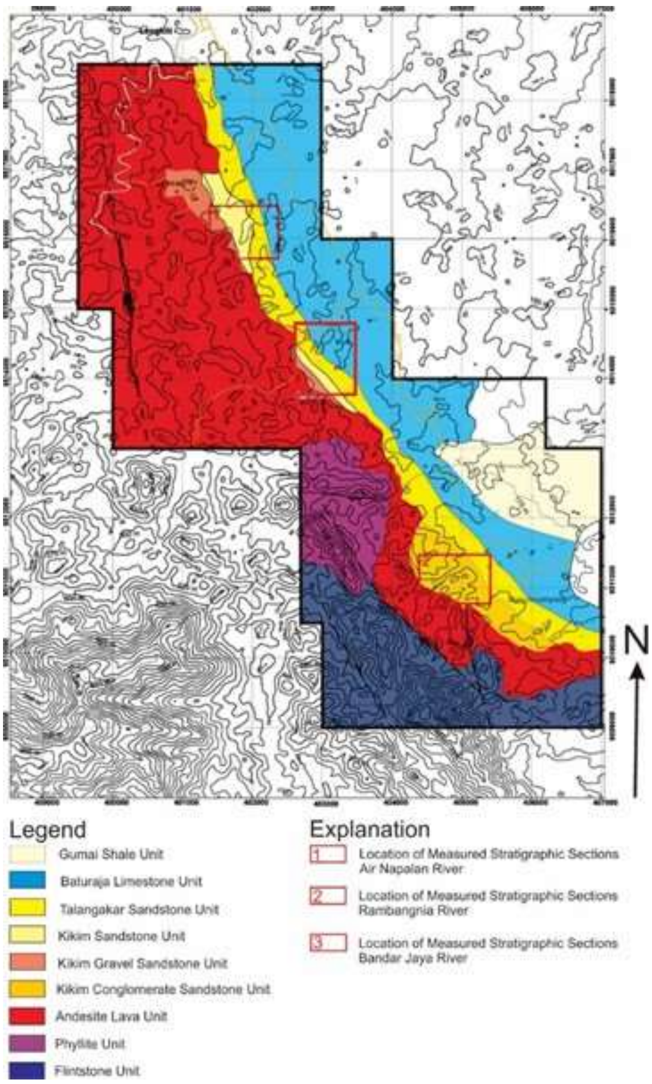


Figure 1. Geological map of Bungincampang village research area, Simpang District, South Ogan Komering Ulu Regency, South Sumatra Province

2. Methodology

Facies analysis was carried out to determine the lithological characteristics to be used to analyze the depositional architecture. This analysis was carried out using lithological data and sedimentary structures in rocks. The approach refers to [5], [6] [7] where the analysis is divided, and the results are named based on differences in grain size, inter-grain relationships and sedimentary structures specific to sedimentary rocks deposited in fluvial environments.

Paleogene depositional facies located in the Garba Hills were determined using primary data obtained from field observations. There were two measured stratigraphic paths, namely the Rambangnia River (Figure 5) and the Air Napalan River (Figure 6). Field data were in the form of rocks and sedimentary structures (architectural elements of rock) that show the facies aspect of each representative observation location, which has specific rock characteristics and is a good outcrop. Facies were determined starting from lithofacies grouping based on differences in grain size, relationships between grains, and sedimentary structures, followed by determining facies associations. Based on the facies associations found, an interpretation of the geometry of architectural elements, depositional environment, and Paleogene depositional mechanisms was generated.

3. Results and discussions

3.1. Fluvial Facies Division

Based on the measured stratigraphic cross-section, sandstone-conglomerate deposits, which were part of the Paleogene Deposits, were obtained. Two stratigraphic sections have been amalgamated based on the profiles at the observation location. The two stratigraphic sections were located on the Rambangnia River with a thickness of ± 107.37 meters and the Air Napalan River with a thickness of ± 11.06 meters.

Figure 2. (A) Massive conglomerate with Massive supported Gravel Matrix facies (Gmm), (B) Laminated siltstone with facies Parallel laminated siltstone and claystone (FI), (C) Conglomerate with Matrix Supported Graded Gravel facies (Gmg), (D) Upper sandstone with facies (St) and claystone bottom with Parallel laminated siltstone and claystone facies (FI), (E) Sandstone with Massive Sandstone (Sm), (F) Claystone with Massive siltstones and mudstones facies (Fsm).

3.2. Lithofacies

Determination of lithofacies can explain the stages of the migration process in sedimentary rocks, which describes how the sediment deposition process occurred in the past [5], [6] Based on the analysis, seven lithofacies were identified by the lithofacies classification scheme [5] (see figure 2 and 3).

Lithofacies Matrix supported Graded Gravel (Gmg) has a dominant inter-grain relationship and is supported by a matrix, namely conglomerate lithology and gravel sandstone with massive sedimentary structures and graded bedding with a lithofacies thickness of 346 centimeters. Lithofacies are located at the bottom, middle, and top of the stratigraphic cross-section. Lithofacies are interpreted as the result of high energy debris flows with high viscosity.

Lithofacies Gravel Matrix supported Massive (Gmm) has a dominant and matrix-supported inter-grain relationships, namely sandstone-conglomerate lithology, gravel sandstone, and conglomerates with massive sedimentary structures. The thickness of the lithofacies in the sandstone-conglomerate unit is 150-400 centimetres. This facies repeatedly occurs within the Kikim conglomerate sandstone unit. Lithofacies are interpreted as the results of high energy debris flows with high viscosity (see figure 3).

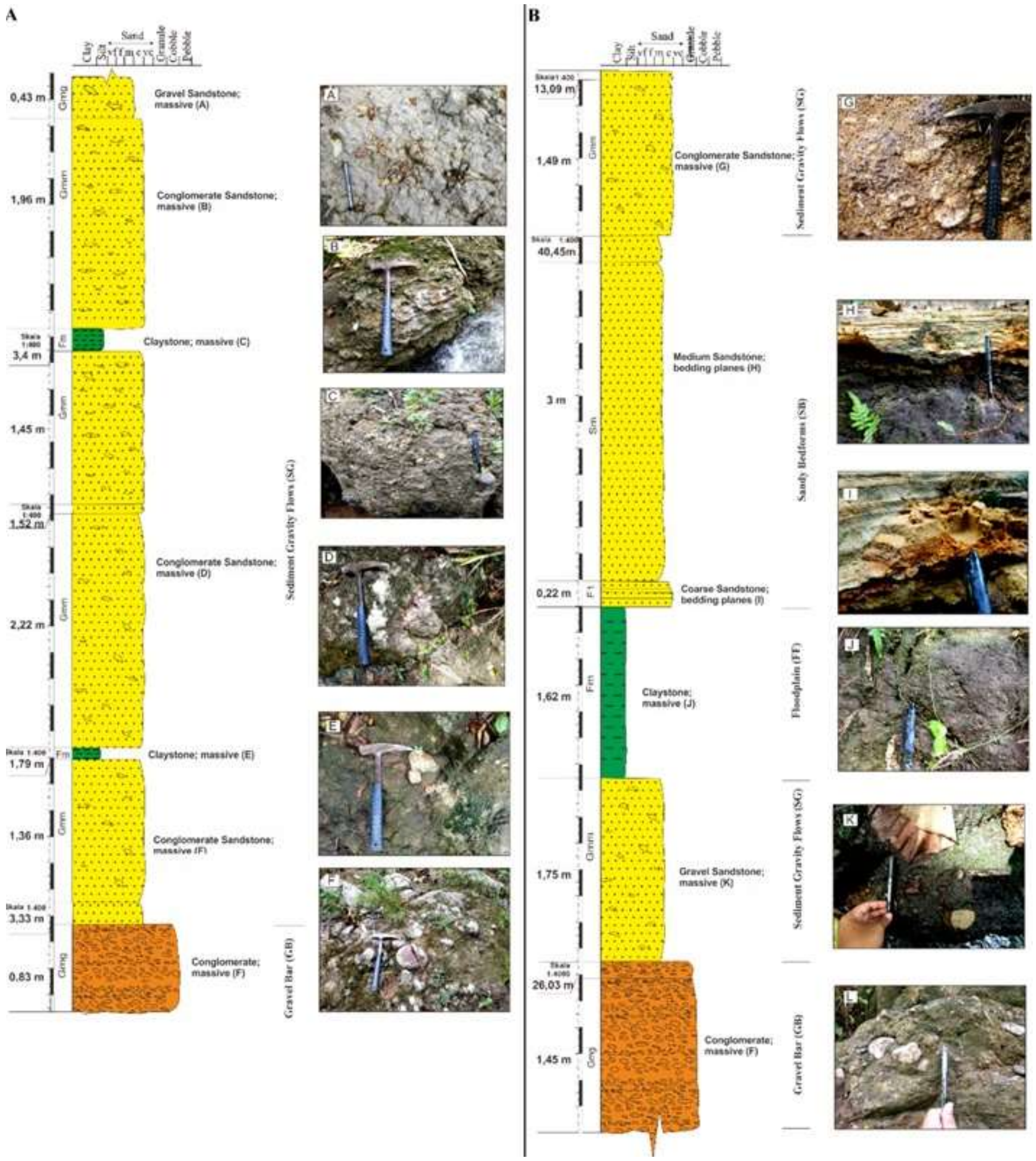


Figure 3. Distribution of facies associations in sandstone-conglomerate units in the Rambangnia River.

Lithofacies Through Cross-Bedded (St) has a medium sand size with a through cross-bedding structure. The facies thickness in the sandstone unit is 170 centimetres. The facies develops in sandstone lithology, which is in the middle of the sandstone-conglomerate unit.

Lithofacies Massive Sandstone (Sm) has medium sand size with massive structure. The facies thickness in the sandstone unit is 6.4-300 centimeters. This facies develops in sandstone lithology in sandstone-conglomerate units. These lithofacies are sedimentary gravity flow deposits.

Lithofacies Horizontally Bedded Sandstones (Sh) has a very fine-very coarse sand with parallel bed structure. Commonly, this layer is parallel to the direction of the current. The thickness of these facies in sandstone units is 14.7-57 centimetres. These facies develop in sandstone lithology at the bottom, middle, and top of the sandstone-conglomerate unit.

Lithofacies Parallel laminated siltstone and claystone (F1) has a silt-clay size with massive, laminated, and ripple cross-laminated structures. The thickness of these facies is 2.7-142 centimetres. This facies develops in siltstone and claystone lithology at the bottom and middle of the sandstone-conglomerate unit. It is interpreted as overbank or abandoned channel deposits and represents deposits of suspension deposition mechanisms and weak traction currents. There are few very small ripples, coal spouts, and diffuse pedogenic nodules.

Facies Massive siltstones and mudstones (Fsm) facies is found in claystone with a massive structure. The thickness of these facies in the conglomerate-sandstone unit is 130 centimetres. This facies develops in claystone lithology located in the centre of the sandstone-conglomerate unit. These facies are interpreted as lagging river deposits.

3.3. Architectural Elements

Five architectural elements can be identified in this study based on the texture and sedimentary structure of the rock (Miall, 1985). The five architectural elements are Sedimentary Gravity Flow (SG), Gravel Bars (GB), Sandy Bedforms (SB), Channel (CH), Overbank Fine (FF) (see table 1).

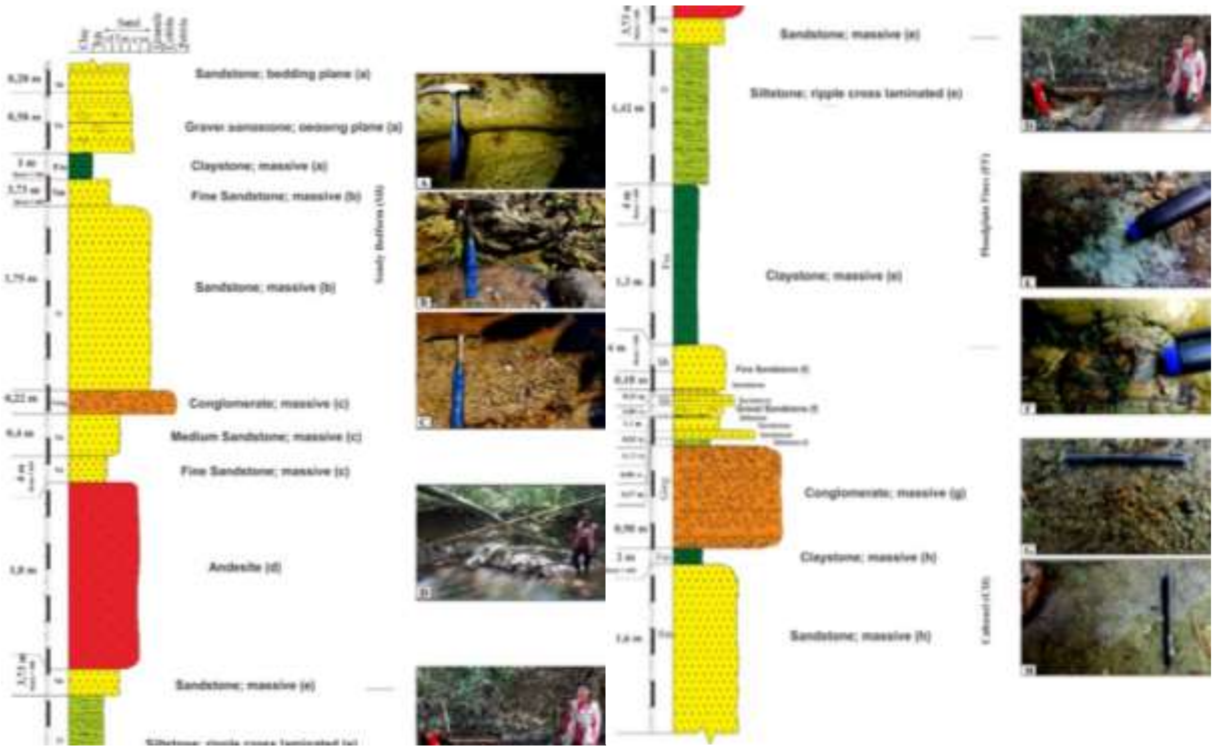


Figure 4. Distribution of facies associations in sandstone-conglomerate units in the Air Napalan River

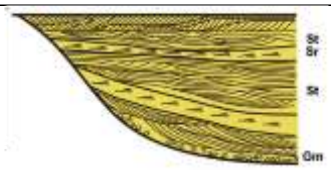
Architectural Element of Sedimentary Gravity Flow (SG), Lithofacies Gmg and Gmm were found in the architectural element of SG. Sandstone-conglomerate facies is located in the lithology in the form of sandstone-conglomerate with a weak upward smoothing structure (see figure 4).

Architectural Element of Gravel Bars (GB), Gmm facies resides in the architectural element of GB. The lithology that develops in the sandstone-conglomerate unit is a conglomerate with a massive structure. Gravel bars are composed of lithofacies with the size of gravel. Gravel bars are composed of lithofacies with the size of gravel. The formation of lithofacies is affected by the transportation process. On gravel bars, it can be seen that the transportation process is irregular at all times. Based on the association of the GB facies, which is composed of material with gravel-sized grains and poor mixing of fine and medium materials as well as the sparse structure of the sediment, it indicates that the GB facies was deposited by gravity flow or debris flow (see figure 2).

Architectural Element of Sandy Bedforms (SB), there are Gmm, thick Sm, St, Sh, Fm, and F1 lithofacies in this element. Architectural elements of Sandy Bedforms are usually sandstone layers with lens geometry, layered, wedged. The thickness of the association of the SB facies reaches 3.13-4.84 meters. It was deposited through a high energy debris flow due to the additional sediment supply from the source. This architectural element is the main element in forming architectural elements and is deposited in a low sinousity river environment (see figure 3).

Architectural Element of Channel (CH), in the channel element (CH), there are Gmm, Sm, Sh, Fm and F1 facies. This element shows an upward smoothing pattern at the bottom of the sandstone-conglomerate unit. The thickness of this element is about ± 3.41 meters. Predominantly, it consists of medium-sized sandstone facies, conglomerates, and siltstone inserts, separated by fine-grained floodplain (FF) facies of siltstone and claystone.

Table 1. Identified architectural elements based on [6], [8], [9]

Architectural Elements	Symbol	Lithofacies	Interpretation
Channel **(CH)**		Gmm, Sm, Sh, and FI	Low sinousity, strong energy or currents, fluvial channel with braided river type
Gravel Bars **(GB)**		Gmm and Gmg	Deposited on the channel bars by debris flow, bedload mechanism, high-strength, high viscosity.
Sedimentary Gravity Flow **(SG)**		Gmm	Deposited by debris flow by low energy, high viscosity.
Sandy Bedforms **(SB)**		Gmm, Sm, St, Sh, Fm, and F1	Deposited in a low-sinuosity river environment through debris flow.
Floodplain **(FF)**		Fsm and FI	Deposits in lagging rivers or back marshes, calm energy, overbank deposits

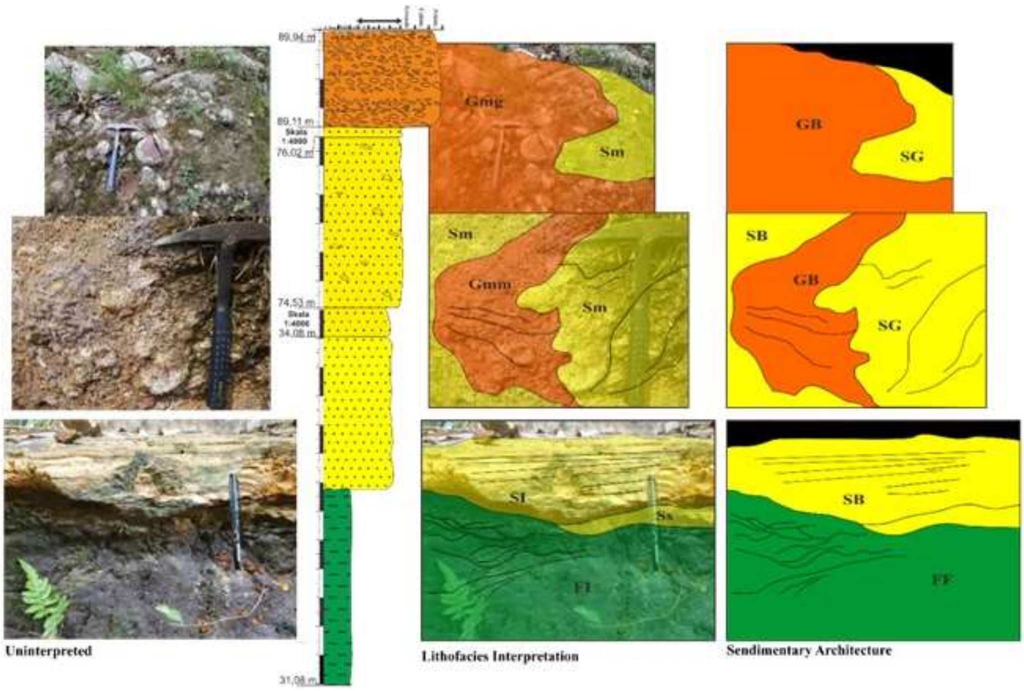


Figure 5. Interpretation of architectural elements in sandstone-conglomerate deposits

Architectural Element of Floodplain (FF), the Fsm and F1 facies are developed on this element in the form of massive claystone and siltstone with a ripple cross-laminated structure and thickness of ± 2.72 meters in the sandstone-conglomerate unit. Floodplain element characterizes deposition in lagging rivers or back swamps. This fact certainly gives an idea of deposition with calm energy. The FF facies association is also part of the overbank deposit of a body of river (see figure 5 and 6).

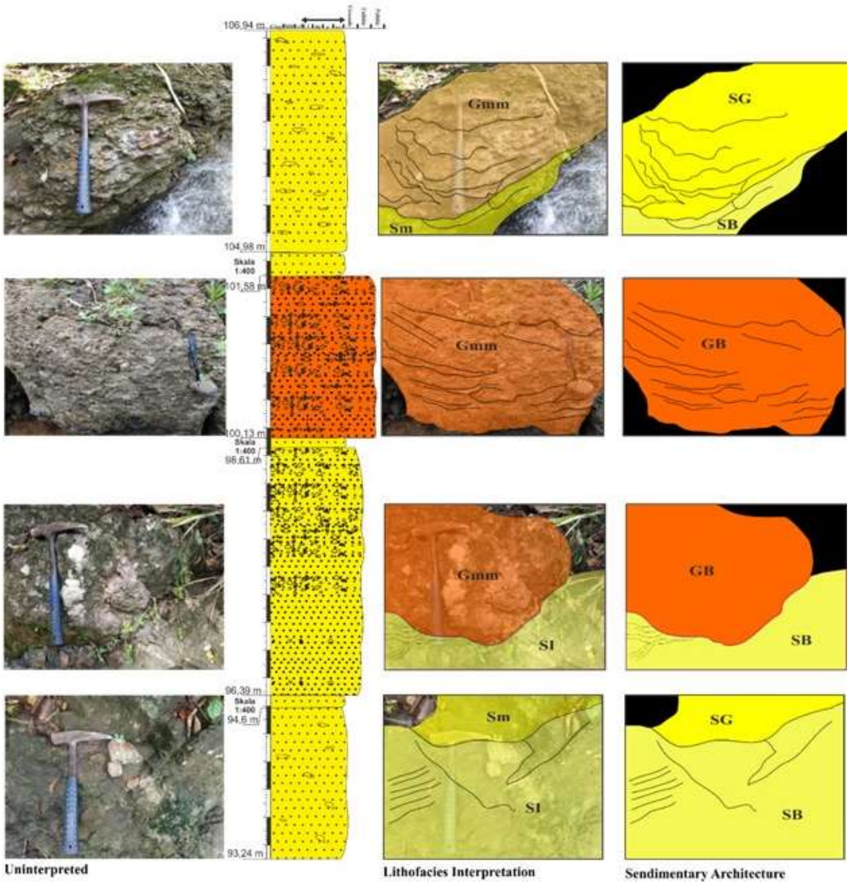


Figure 6. Interpretation of architectural elements in sandstone-conglomerate deposits

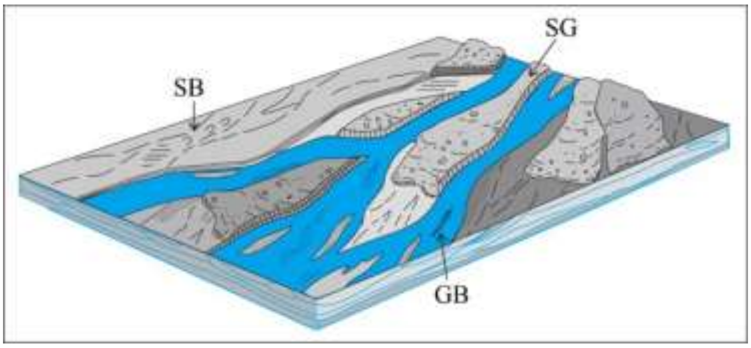


Figure 7. Model of gravel braided rivers with sedimentary gravity flows (Miall, 1985)

3.4. Sandstone-conglomerate deposits and depositional environment

The succession of conglomerate-sandstone deposits is dominated by sand-gravel sized material (see figure 7). There are siltstone and claystone inserts as minor F1 and Fsm facies with a structure that develops in an ambiguous cross. The bottom of the succession characterized by the presence of medium-grained sandstone-conglomerate indicates an increase or stronger current velocity during deposition, which is then interpreted as a channel filling process. Then, in the next phase, fine-sized sedimentary material appears is interpreted as overbank deposits. The overbank fine facies shows a change in current from the previous strong current to a weaker current. Initially, coarse grains will settle to the bottom according to the existing rock mass, and fine grains will settle at the top due to the small density of the rock. The upper part of the succession is interpreted as the dominance of the GB, SG, and SB facies groups. This fact indicates a stronger current change, which may be caused by the many water supply sources and sediment material from the upstream channel, resulting in a sudden change in current (see figure 8).

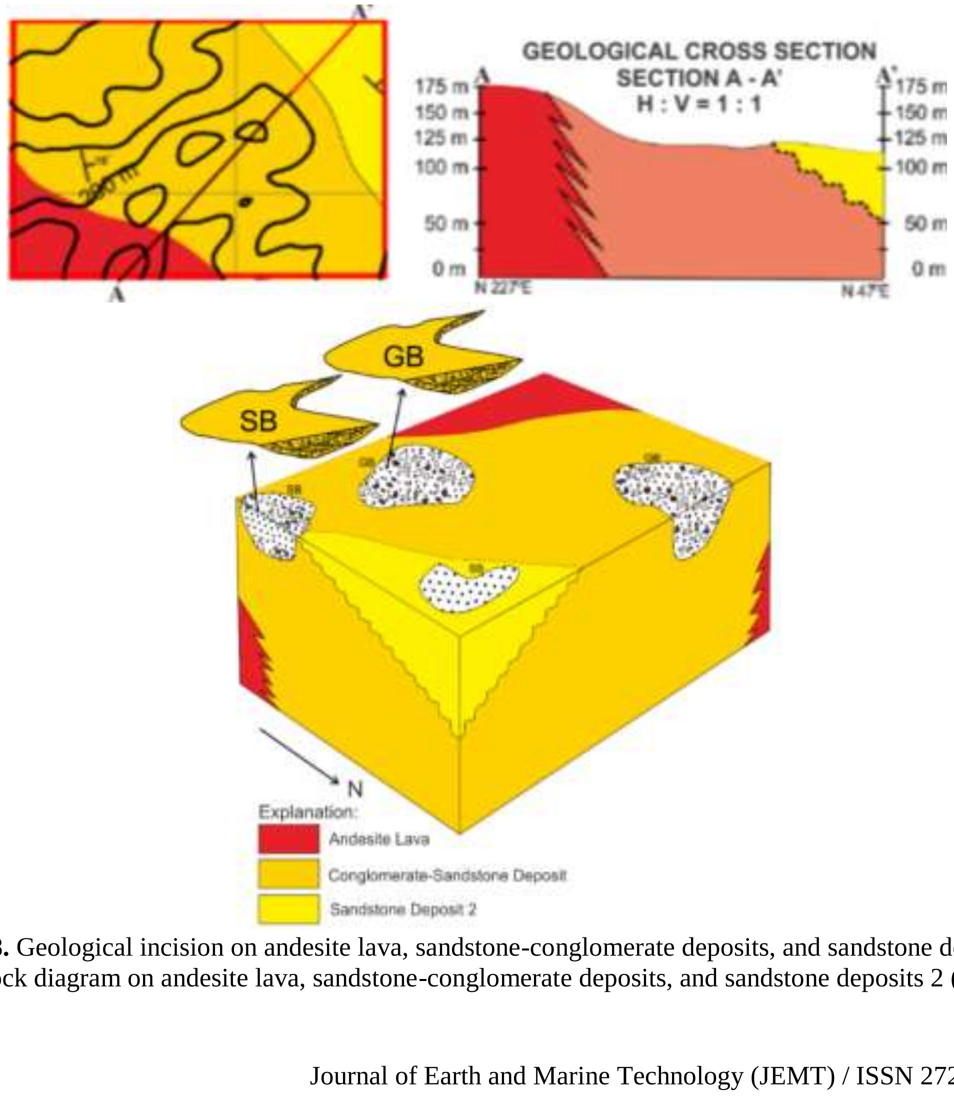


Figure 8. Geological incision on andesite lava, sandstone-conglomerate deposits, and sandstone deposits 2 (top),block diagram on andesite lava, sandstone-conglomerate deposits, and sandstone deposits 2 (bottom)

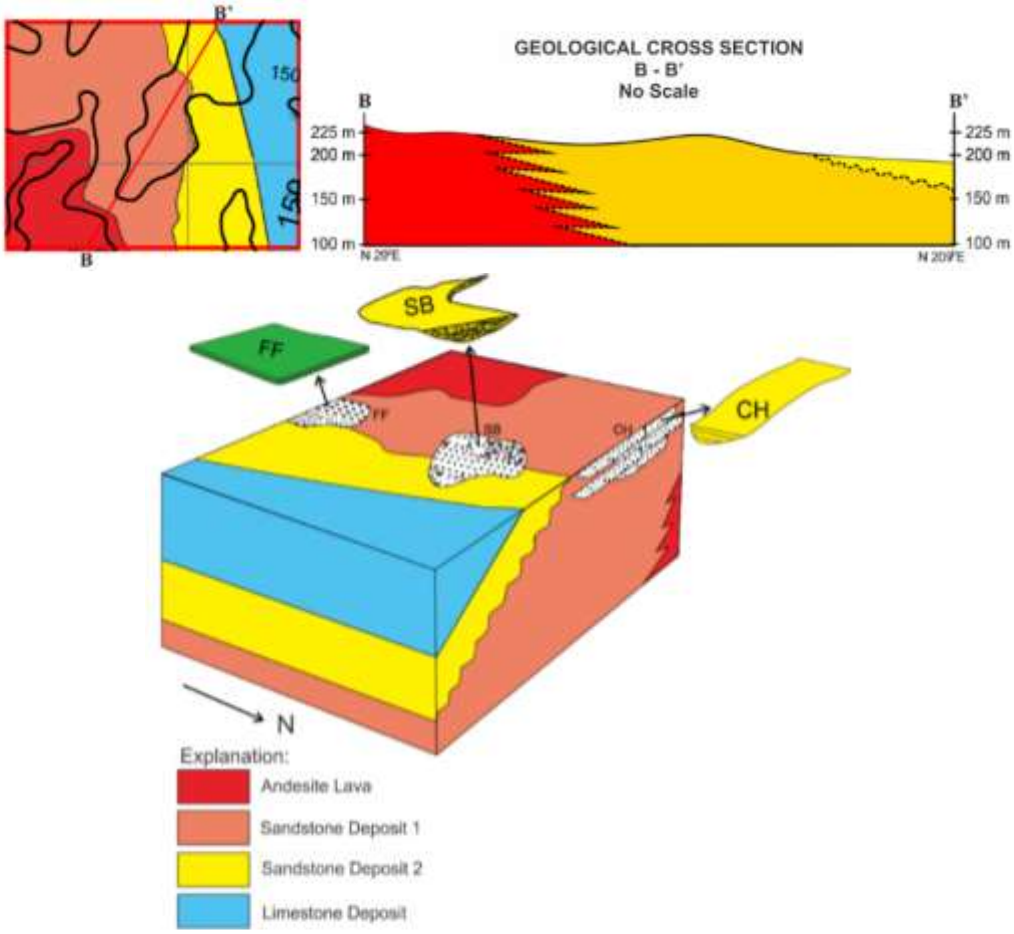


Figure 9. Geological incision of lava, sandstone deposit 1, sandstone deposit 2, and limestone deposit (top),block diagram of lava, sandstone deposit 1, sandstone deposit 2, and limestone deposit (bottom)

Based on this description, it can be seen that the depositional environment of the study area is a fluvial environment. Then, by looking at the large grain size of the sediment, the large sediment load, the high flow velocity, the fast deposition, the depositional environment is described in the braided river model. The dominance of sedimentary materials that tend to be coarse and the number of GB, SG, and SB facies associations indicate many river bars, which are the characteristic of a braided river. The braided river has a bedload sediment transport mechanism (creeping on the riverbed). The geometry of a braided river has a high slope, wide river geometry, and the highest river slope among all types of rivers. The braided river also has a straight to curved river level, with more than one channel multi-channel), and thalweg shift that rarely occurred (the deepest point of the river) (see figure 9).

The dominant coarse material also indicates that it is close to the source (proximal). Commonly, the kind of river in the areas close to the source is a braided river. The model obtained based on the analysis results is gravel braided rivers with sedimentary gravity flows.

4. Conclusion

Based on observations on the measured trajectories of the Rambangnia River and Air Napalan carried out in the research area (figure 4), this area is in a fluvial depositional environment. In facies analysis, there are seven lithofacies, namely Matrix supported Graded Gravel (Gmg), Gravel Matrix supported Massive (Gmm), Through cross-bedded (St), Massive Sandstone (Sm), Horizontally bedded sandstones (Sh), Parallel laminated siltstone and claystone (F1), Massive siltstones and mudstones (Fsm).

The facies associations obtained are Sedimentary Gravity Flow (SG), Gravel Bars (GB), Sandy Bedforms (SB), Channel (CH), Overbank Fine (FF), and the type of river is braided river with gravel braided rivers model with sedimentary gravity flows.

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