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Comprehensive Facies Analysis and Depositional Environments of the Kikim Formation, Garba Mountain, South Palembang Subbasin, Indonesia

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Abstract
This study provides an exhaustive facies analysis of the Kikim Formation within the Garba Mountain area of the South Palembang Subbasin, emphasizing the stratigraphic significance and depositional environments during the Paleogene period. Utilizing field data collected from the Bumi Agung and Batu Belang measurement lines, this research categorizes various lithofacies using Miall's (1978) classification scheme, identifying eight distinct lithofacies and four facies associations indicative of a predominantly fluvial depositional setting. The results depict a detailed sedimentological framework, showing that the Kikim Formation was characterized by a braided river system with significant gravel and sandstone deposits. This analysis not only sheds light on the geological history and processes shaping the South Sumatra Basin but also enhances the understanding of its potential hydrocarbon reservoirs. By detailing the lithological diversity and facies distribution, this paper contributes to the broader geological knowledge required for effective exploration and management of the region's natural resources.

1. Introduction

The South Sumatra Basin, a significant hydrocarbon-bearing region in Indonesia, encompasses a complex geological and tectonic history that has been extensively studied due to its prolific oil and gas reservoirs [1], [2]. This basin is characterized by its diverse stratigraphic units, among which the Kikim Formation stands out due to its Paleogene origins and its implications for understanding the region's sedimentary and tectonic evolution [3], [17].

The Kikim Formation, predominantly located in the Garba Mountain area of the South Palembang Subbasin, presents a unique opportunity to study the facies architectures and depositional environments that have influenced its development. Previous studies have highlighted the significant role of fluvial processes in shaping the geological characteristics of this formation [4], [8]. According to Miall's well-established classifications, the identification and analysis of lithofacies and architectural elements within these deposits provide insights into the paleoenvironmental conditions during the Paleogene period [5], [6].

Recent facies analyses in similar geological settings have underscored the importance of detailed architectural element analysis to decipher the depositional mechanisms and to better predict the locations of potential hydrocarbon reservoirs [7], [10], [11]. This research builds upon the foundational work by Barber et al. [1], Bishop [2], and others, extending the understanding of the South Sumatra Basin's geological framework [9], [12], [15].

This study aims to conduct a comprehensive facies analysis of the Kikim Formation, employing Miall's framework to classify and interpret the various lithofacies and their depositional environments. By integrating field data with sedimentological analyses, we seek to refine the stratigraphic models for the Paleogene sedimentary rocks in this region, potentially aiding in the exploration and development of its hydrocarbon resources [13], [14], [16], [18].

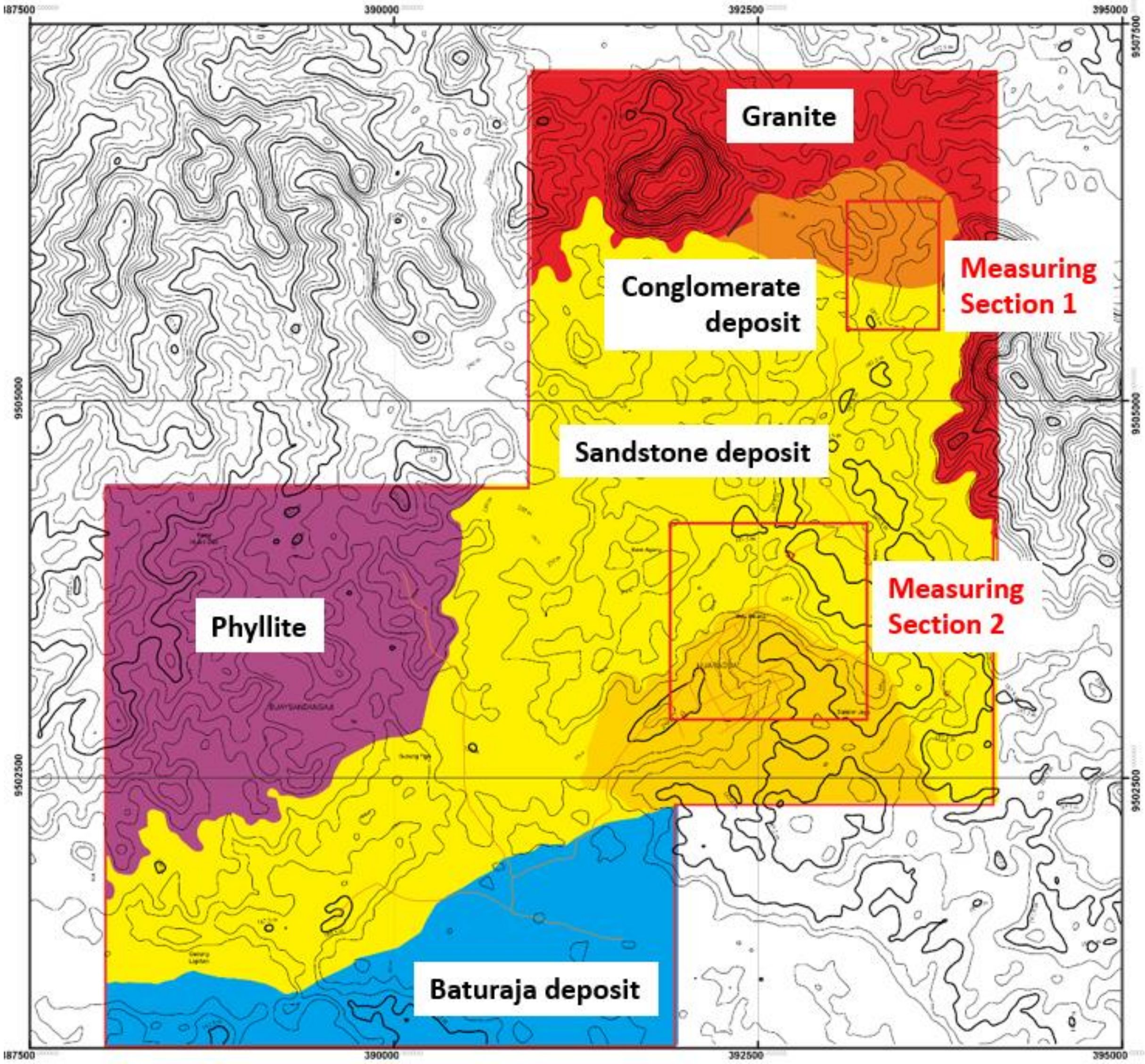

Figure 1. Geologi map of Muaradua Area, South Ogan Komering Ulu, South Sumatra Province.

2. Regional geology

The South Sumatra Basin, situated to the east of the Bukit Barisan mountain range, extends in a northwest-southeast direction. This basin is categorized as a back-arc basin, bordered by the Barisan Mountains to the southwest and the Pre-Tertiary Sunda Shelf to the northeast. The region is noted for its significant oil and natural gas production, primarily influenced by its complex sub-basin structure [1], [2].

The basin is divided into several sub-basins: the Jambi Sub-basin (North Palembang), the Central Palembang Sub-basin, and the South Palembang Sub-basin (Palembang Complex), with the focal area of this study located within the North Palembang sub-basin. This stratification aligns with the geological mappings detailed by various researchers [1], [3].

According to the sequential stratigraphy as outlined by Gafoer, Amin, and Pardede, the oldest rocks are the Basement Rock, above which the terrestrial Garba, Kikim, and Lahat Formations were deposited [4]. This stratigraphic sequence extends through a transgressive phase, marked by the deposition of the Talang Akar, Batu Raja, and Gumai Formations in marine environments, and concludes with a regressive phase involving the deposition of the Air Benakat Formation in shallow marine settings, transitioning through the Muara Enim Formation and concluding with the terrestrial Kasai Formation [4], [5].

The tectonic history of the basin is characterized by three major phases. The initial Compression Phase from the Early Jurassic to the Cretaceous involved significant sedimentary changes, where Mesozoic sediments were metamorphosed, folded, and fractured into structural blocks, thus defining the basic structural pattern of the basin [3], [6]. The subsequent extensional phase from the Late Cretaceous to the Early Tertiary facilitated N-S and WNW-ESE tectonism along with volcanic activities and sedimentation influenced by Paleozoic and Mesozoic orogenies and weathering of Pre-Tertiary rocks [3]. The final Compression Phase in the Plio-Pleistocene led to an uplift in the Bukit Barisan Mountains and the development of the Sumatran strike-slip fault, which runs along the mountain range, influencing the basin's current structural orientation [7].

3. Methodology

This study employed facies analysis to elucidate the lithological characteristics and depositional architecture of the Kikim Formation, utilizing data derived from sedimentary structures and lithology observed within fluvial environments. The methodology was guided by the classification system proposed by Miall, which categorizes facies based on grain size, intergranular relationships, and distinctive sedimentary structures [5], [6].

Field mapping was conducted at two key stratigraphic sections: Bumi Agung and Batu Belang. Detailed stratigraphic cross-sections were recorded at these locations, capturing the facies characteristics relevant to each site, including lithological properties and the quality of outcrops (Figures 3 and 4). This primary data served as the foundation for subsequent facies determination and analysis.

The process began with the identification and grouping of lithofacies according to variations in grain size and the relationships between grains and sedimentary structures. Following the initial classification, facies associations were defined to further interpret the depositional environment. These associations helped in understanding the architectural geometry and depositional mechanisms at play within the Kikim Formation, particularly in the context of the identified fluvial systems.

This analytical approach facilitated a comprehensive reconstruction of the paleoenvironmental conditions prevailing during the deposition of the Kikim Formation, thus providing insights into the fluvial dynamics and sedimentary processes within the South Sumatra Basin [5], [6].

4. Results

Fluvial Facies Division

Detailed measurements of the stratigraphic sections at Bumi Agung and Batu Belang have yielded critical insights into the depositional characteristics of the Kikim Formation. These sections, with respective lengths of approximately 158.82 m at Bumi Agung and 177.50 m at Batu Belang, revealed a complex assemblage of conglomerate and sandstone deposits. The granularity and composition of these deposits provide key evidence of the dynamic fluvial processes that have shaped this region over geological timescales, highlighting their importance in reconstructing paleoenvironmental conditions.

Table 1. Lithofacies found in each deposit

Facies	Conglomerate deposit	Sandstone deposit
Gmm (matrix-supported gravel)	v	v
Gmg (gravel matrix supported massive)	v	v
Gm (massive gravel	v	-
Sh (horizontally bedded sand)	v	v
SI (low-angle cross-bedded sand)	v	-
Sm (massive sand)	v	v
Fsm (laminated sandstone and mudstone)	-	v
Fm (massive mudstone-siltstone)	-	v
C (carbonaceous mud)	-	v

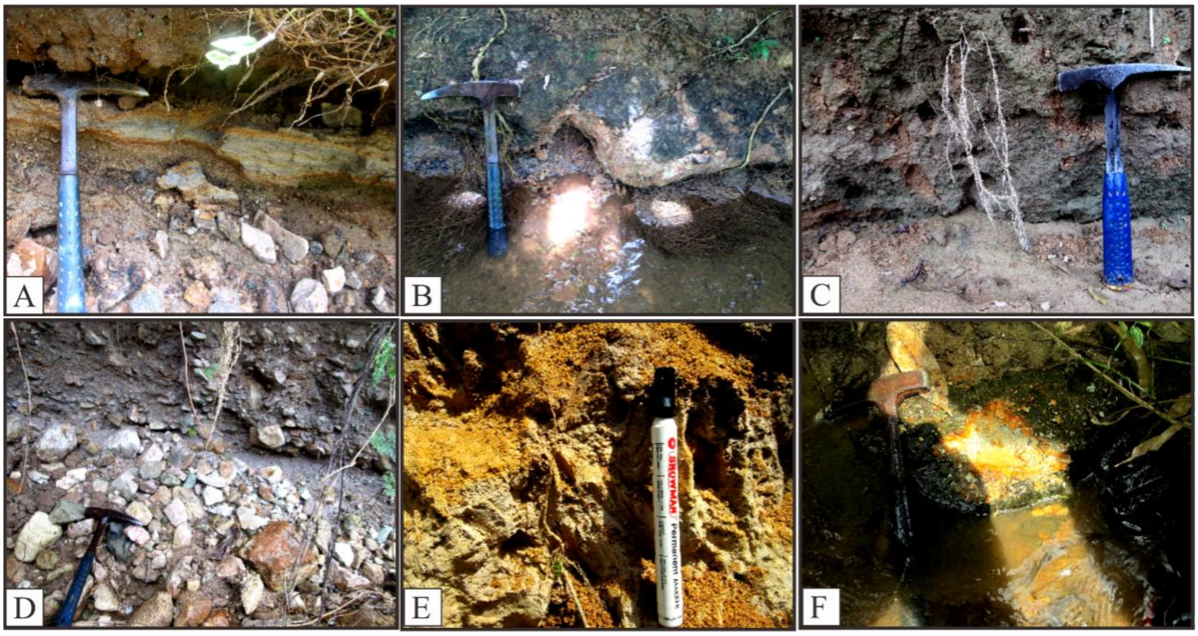

Figure 2. (A) Layered structure sandstone with the horizontally bedded sandstones (Sh) facies, (B) Laminated structure siltstone with the Massive siltstones and mudstones (Fsm) facies, (C) Sandstone with the Massive Sandstone (Sm) facies, (D) Conglomerate with the Matrix Supported Graded Gravel (Gmg) facies, (E) Sandstone with Massive Sandstone (Sm) facies, (F) Mudstone with Massive Mudstone-Siltstone (Fm) facies.

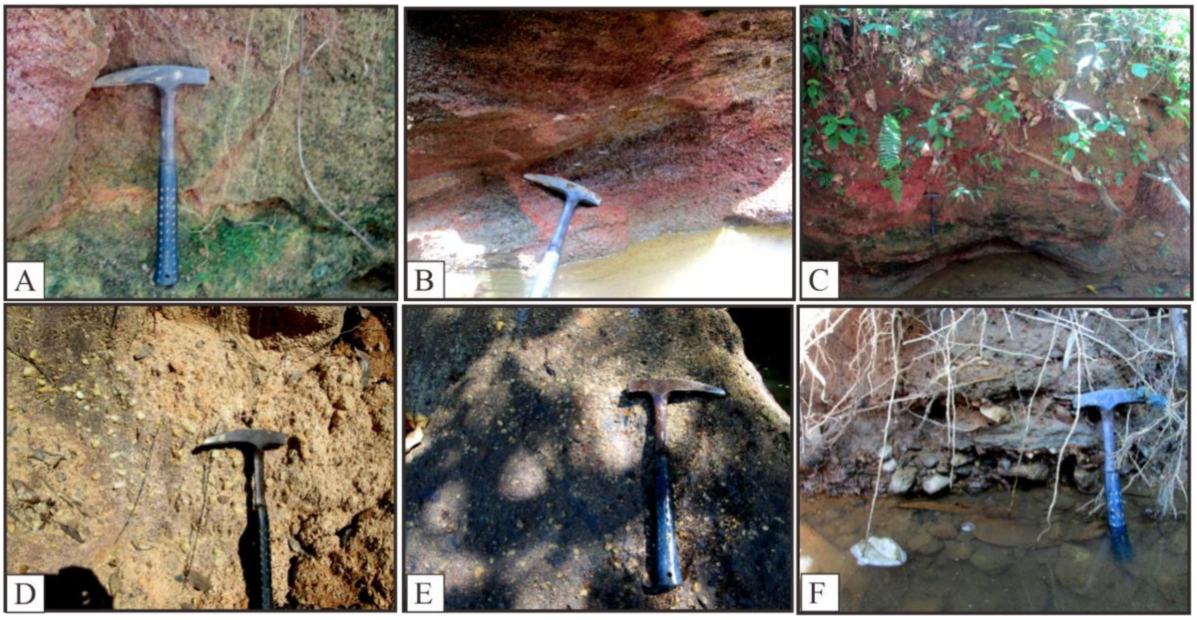

Figure 3. (A) Sandstone with the Massive Sandstone (Sm) facies, (B) Layered structure sandstone with the Horizontally bedded sandstones (Sh) facies, (C) Mudstone with the Massive Mudstone-Siltstone (Fm) facies, (D) Conglomerate with the Gravel Matrix facies Supported Massive (Gmm), (E) Sandstone with Massive Sandstone (Sm) facies, (F) Conglomerate with Matrix Supported Graded Gravel (Gmg) facies.

Lithofacies Analysis

Our comprehensive analysis delineated ten distinct lithofacies within the formation, with a dominance of coarse-fine sandstone textures that suggest a varied range of depositional energies and sediment transport mechanisms. Conglomerates and clay-dominated facies were observed less frequently, indicating localized depositional environments or episodic sediment supply [5], [6]. The following is an explanation of each lithofacies in Table 1.

1. **Gravel Matrix Supported Massive (Gmg) Lithofacies**: Predominantly found across several stratigraphic sections, this lithofacies comprises matrix-supported conglomerate and gravelly sandstone with massive and graded bedding structures, indicative of high-energy debris flows. The facies thickness varies between 60 cm and 100 cm, reflecting the intense depositional dynamics during its formation.
2. **Massive Gravel (Gm) Lithofacies**: This lithofacies is characterized by a non-matrix-supported structure, suggesting deposition from unconfined debris flows. It is prevalent in conglomerate lithologies and varies in thickness from 50 to 125 cm, providing insights into the energetic conditions prevalent at the time of deposition.
3. **Massive Sandstone (Sm) Lithofacies**: With medium-sized sand grains and a massive structure, this lithofacies spans thicknesses from 14 cm to 200 cm. It is interpreted as the result of sedimentary gravity flow deposits, reflecting a range of depositional velocities and sediment loads.
4. **Horizontally Bedded Sandstones (Sh) Lithofacies**: Consisting of very fine to coarse sands with parallel bedding aligned with the prevailing current directions, this lithofacies showcases its development across different stratigraphic levels with thicknesses ranging from 22 cm to 50 cm. It indicates a more tranquil flow regime relative to other facies.
5. **Low Angle Cross-bedding Sand (Sl) Lithofacies**: Featuring very fine to medium sand grains and cross-bedding at angles less than 15 degrees, this lithofacies, with a consistent thickness of 30 cm, marks dynamic sedimentary processes under fluctuating flow conditions within the fluvial system.
6. **Massive Mudstone-Siltstone (Fm) and Massive Siltstones and Mudstones (Fsm) Lithofacies**: These lithofacies are identified in mudstone lithologies with massive structures and vary in thickness from 10 cm to 150 m. They are representative of depositional remnants from riverine or backwater swamp environments, providing clues about the low-energy phases of the river's history.
7. **Carbonaceous Mud (C) Lithofacies**: This lithofacies comprises black mudstone and coal with a massive structure, varying in thickness from 2 cm to 50 cm. Typically located in central parts of the deposits, it is associated with overbank or abandoned channel deposits, indicative of periods of reduced flow or stagnant waters.

Architectural Elements

Four architectural elements were delineated to assist in interpreting the depositional environment and sedimentary architecture of the region:

- **Gravel Bars (GB)**: Composed of Gmm, Gmg, and Gm lithofacies, these elements signify irregular transport processes under high-energy conditions, often forming key structural features within the channel.
- **Sandy Bedforms (SB)**: Dominated by Gmm, Sm, Sh, and Fm lithofacies, these features suggest deposition in a low-sinuosity river environment, heavily influenced by sedimentary gravity flows.
- **Channel (CH)**: This element incorporates Gmm, Sm, Sh, Sl, Fm, and Fsm lithofacies, displaying a well-defined upward gradation pattern characteristic of channel fills within the fluvial depositional system.
- **Floodplain (FF)**: Marked by Fsm and Fm lithofacies with ripple cross-laminated structures, these deposits reflect sedimentation under conditions of reduced energy, typical in overbank areas or abandoned channels [5], [6].

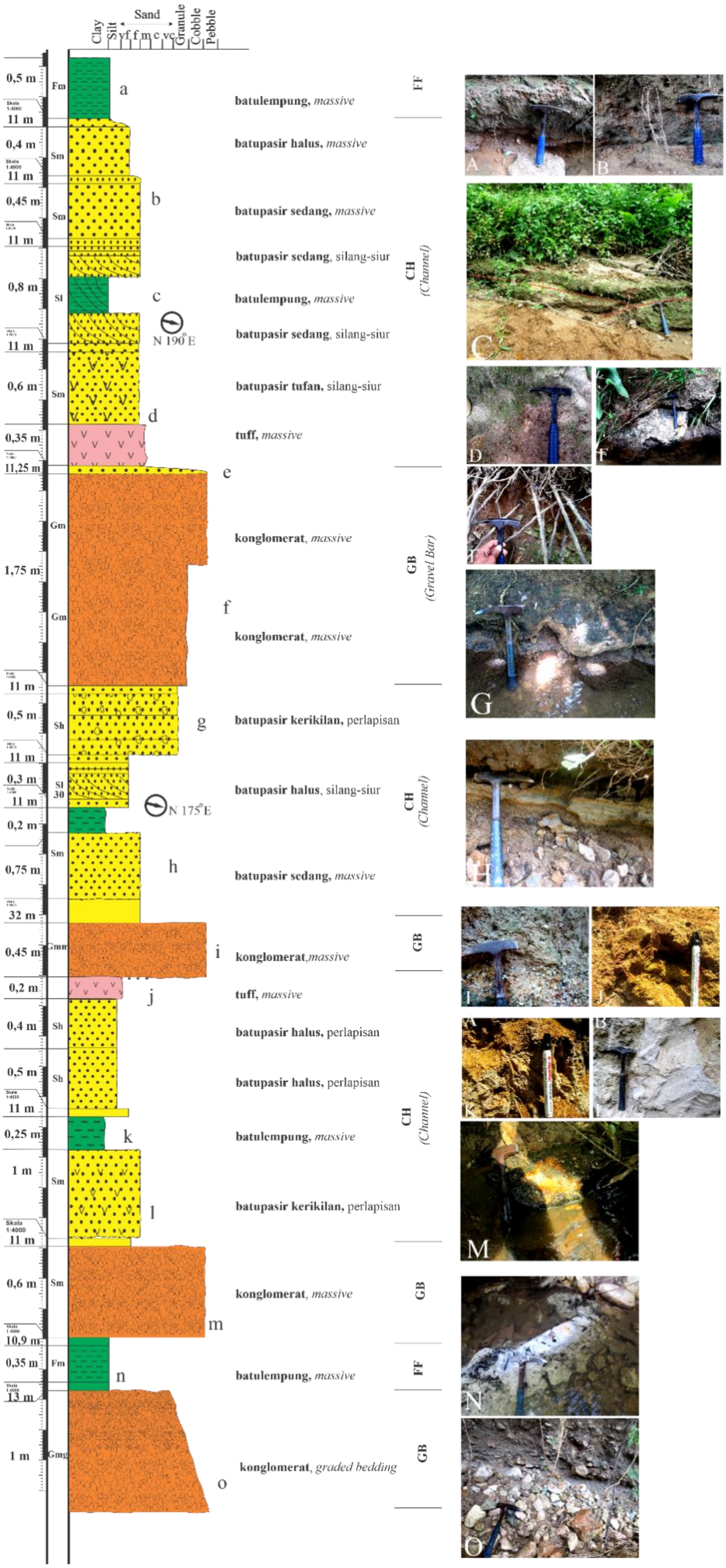

Figure 4. Division of facies associations in sandstone-conglomerate at the Bumi Agung location

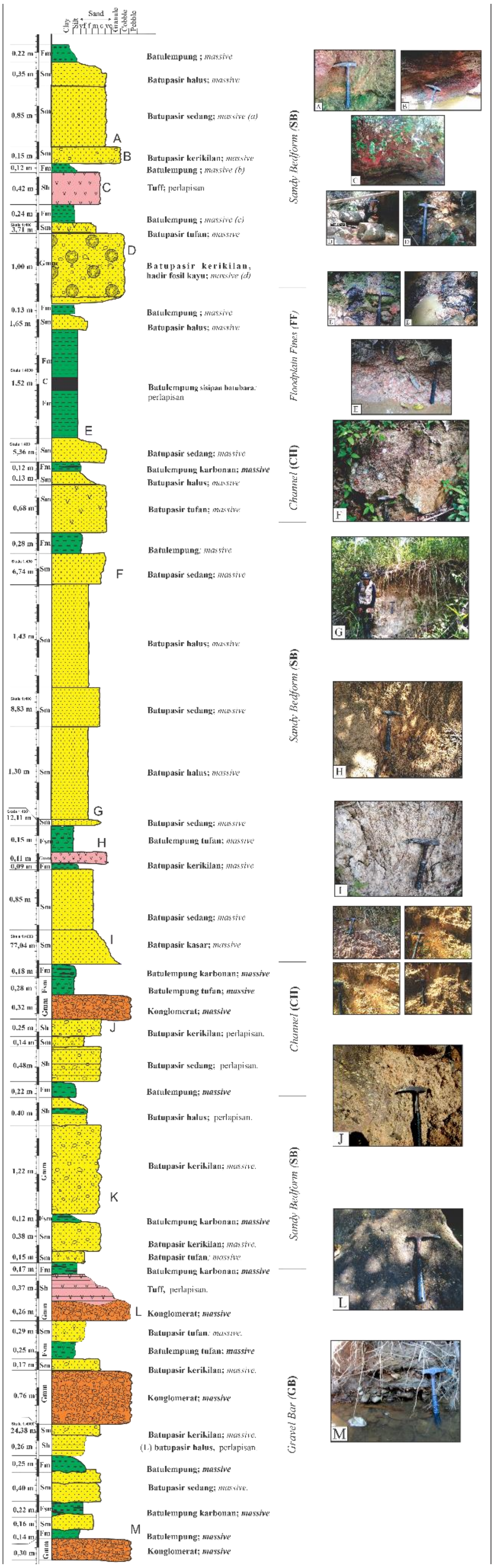

Figure 5. Division of facies associations in the sandstone conglomerate at the Batu Belang location.

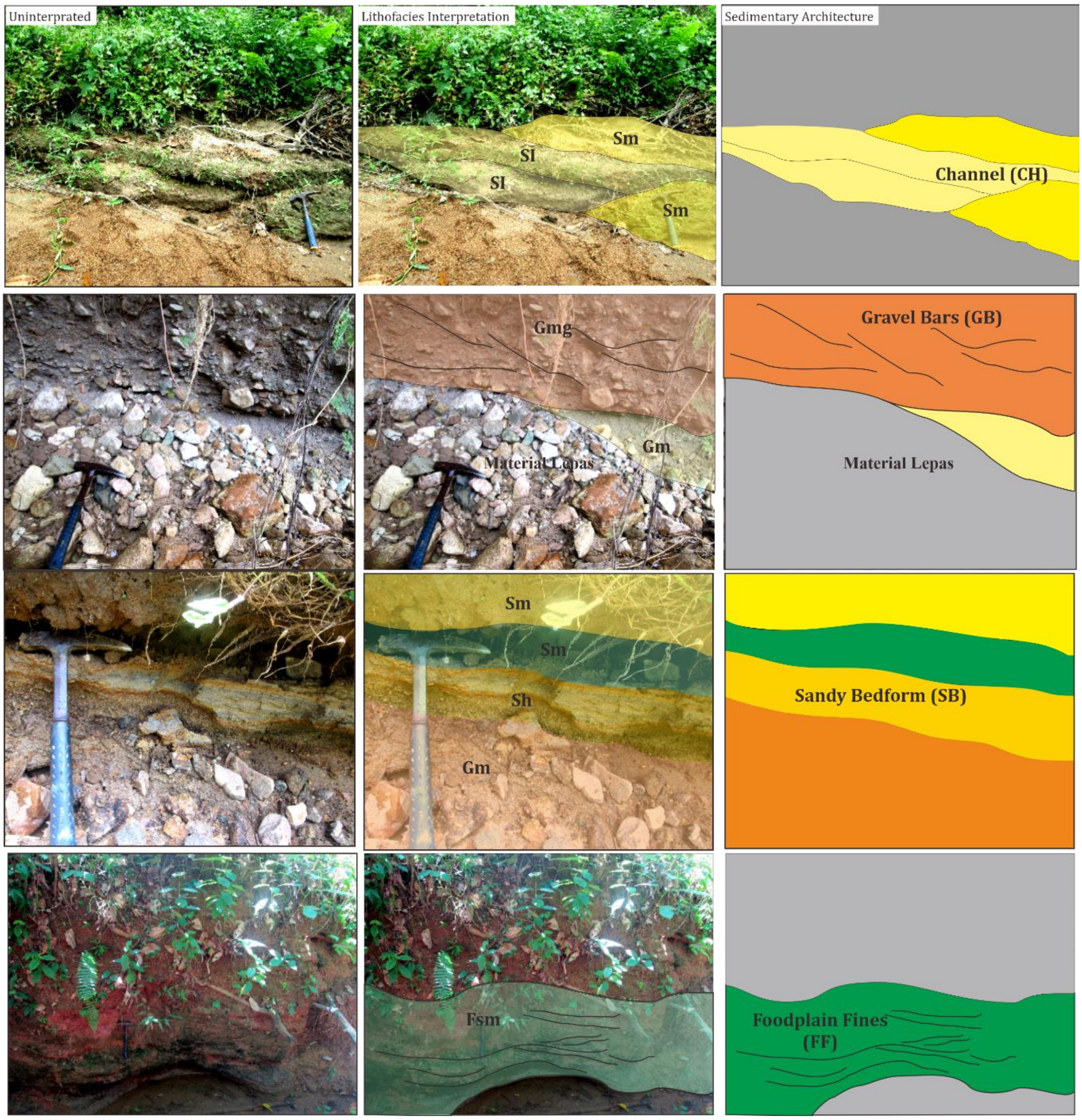

Figure 6. Interpretation of architectural element in Conglomerate deposit and sandstone

The detailed illustrations and photographs (Figures 2-6) included in this analysis provide a visual representation of the diverse lithofacies and their spatial distribution across the examined sections. These visual aids are crucial for substantiating the sedimentological interpretations and for providing a clearer understanding of the depositional environments that prevailed during the formation of the Kikim Formation.

5. Discussion

Conglomerate Deposit Analysis

The examination of the conglomerate deposits at the Bumi Agung location revealed a complex array of lithofacies, with a dominance of sand-cobble-sized material. This diversity is well-captured through the application of Miall's lithofacies classification from 1978 [5]. The identified facies—Gmm, Gmg, Gm, Sm, Sh, SI, Fm, and Fsm—illustrate a range of depositional processes from gravity flows to finer sediment deposition indicative of varying energy levels within the fluvial system.

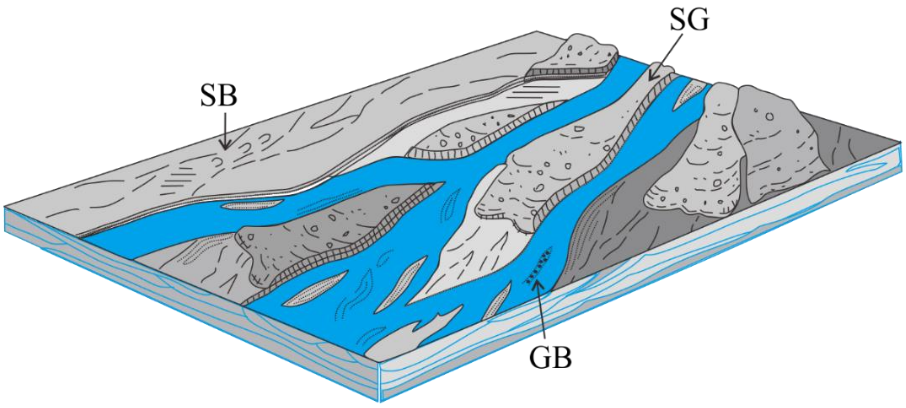

Figure 7. River model of Gravel braided rivers with sedimentary gravity [6]

Channel architectural elements, as described by Miall in 2006 [6], were particularly prominent, showing smooth upward transitions that suggest a dynamic interaction between erosion and deposition processes. The lithofacies comprising these channels, including Gmg, Gmm, Sm, Sh, and Fm, indicate a sequence from high-energy deposition to more stabilized sedimentary environments. This transition reflects the channel's response to both autogenic processes and allogenic controls, such as climatic variations or tectonic activities influencing sediment supply and river morphology.

Sandstone Deposit Analysis

At the Batu Belang location, the sandstone deposit, named Sandstone Deposit 1, displayed a similar complexity. The primary lithofacies identified—Gmm, Gmg, Sm, Sh, C, Fm, and Fsm—suggest a depositional environment characterized by both high-energy and quieter phases, accommodating a wide range of particle sizes from gravel to clay [5], [6]. This variation in grain size and the presence of distinctive architectural elements like Channels (CH), Sandy Bedforms (SB), Floodplains (FF), and Gravel Bars (GB) point to a highly dynamic fluvial system capable of supporting diverse sedimentary structures.

These findings indicate a predominant influence of coarse to fine sandstone facies, transitioning from high-energy gravelly layers to lower-energy clay-rich layers. This gradational change is typical of fluvial environments where episodic floods or steady declines in river energy lead to differential deposition of sediments.

Depositional Environment

The conglomerate and sandstone deposits strongly point to a braided river environment as the predominant fluvial model [5]. The characteristics of these deposits—large sediment grain size, high sediment load, and rapid deposition rates—align with the nature of braided rivers, which are typically marked by their ability to carry large amounts of coarse sediment across wide, shallow channels [5], [6].

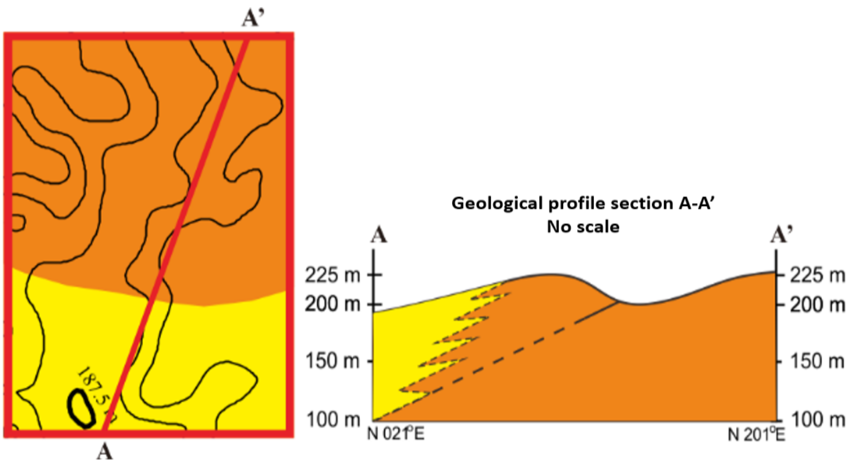

Figure 8. Geology incision in Conglomerate and sandstone deposits

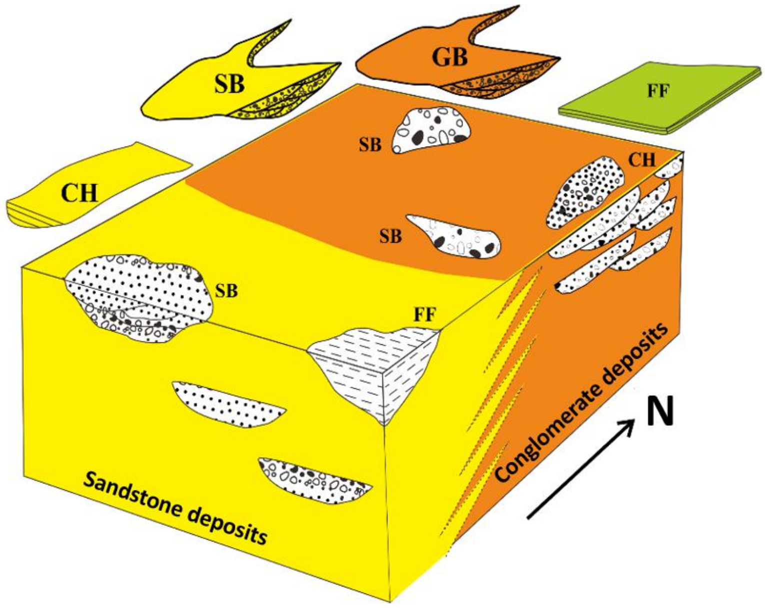

Figure 9. Block diagram of Conglomerate and sandstone deposits

The proximity of these deposits to their sediment source is evidenced by the coarse nature of the material, supporting the hypothesis of a proximal depositional environment typical of braided river systems as described by Nichols in 1999 [7]. Such rivers are generally characterized by multiple channels and lack significant longitudinal shifts in channel position, known as Thalweg shifts, which further supports the observed sedimentological data.

This braided river system, with its complex interplay of erosional and depositional processes, illustrates a dynamic river environment capable of both shaping and being shaped by local and regional geologic processes. The identification of gravel braided rivers with sedimentary gravity flows, as modeled by Miall in 1985 [5], underscores the significant role of gravity flows in transporting and depositing the sediment load in such high-energy river systems.

Depositional Characteristics of the Kikim Formation

The Kikim Formation's conglomerate and sandstone deposits, extensively examined at the Bumi Agung and Batu Belang locations, demonstrate a diverse range of lithofacies, indicative of dynamic depositional processes [5]. The lithofacies classification by Miall [6] aligns well with these findings, providing a framework that is supported by the broader characterizations of fluvial deposits by Miall in subsequent studies [7]. The variability in sediment size and composition observed in these locations mirrors global sedimentological frameworks described by Ryacudu [10] and reflects the complex interactions between fluvial dynamics and sediment supply documented by Nichols [16].

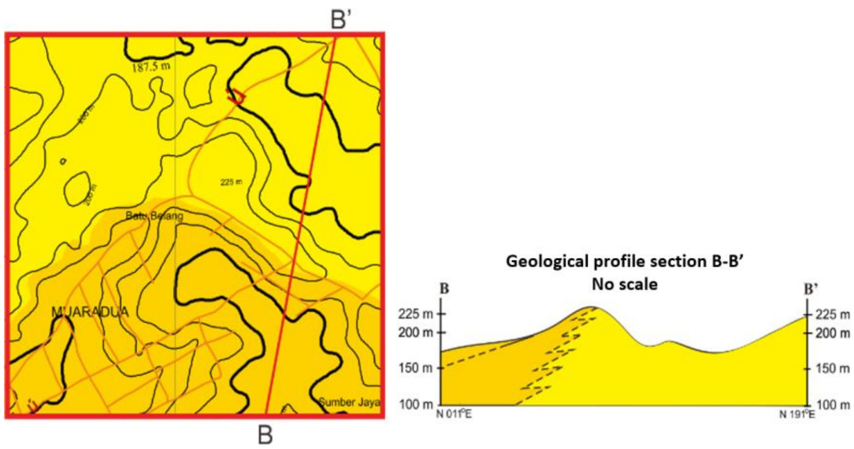

Figure 10. Geology incision of sandstone deposit and sandstone deposit 1

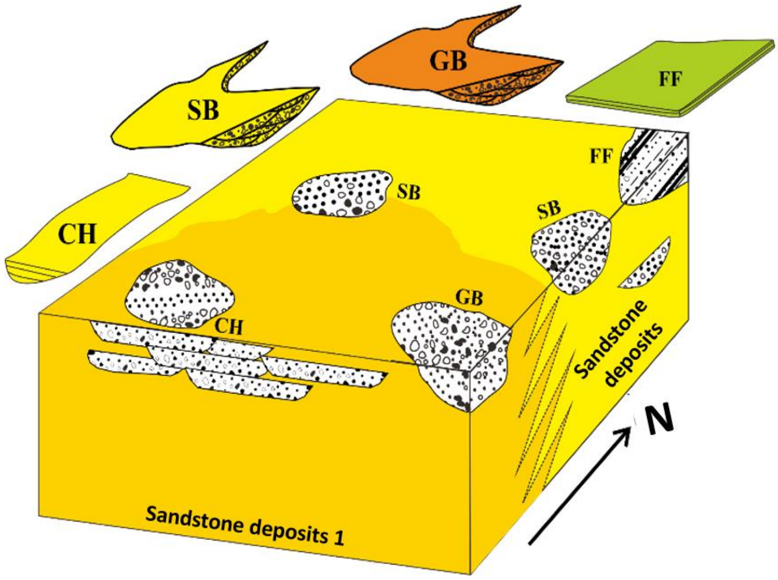

Figure 11. Block diagram of geology incision of sandstone deposit and sandstone deposit 1

The accompanying figures (Figures 7-11) provide a visual representation of the gravel braided river model and detailed geological incisions, enhancing the understanding of the sedimentary architecture and depositional dynamics of the conglomerate and sandstone deposits.

Channel Dynamics and Architectural Elements

The channel dynamics within the Kikim Formation reveal significant insights into the fluvial architecture. These include channel fill sequences that show smooth upward transitions, suggesting periods of increased flow and sediment supply, as discussed by Miall [7]. These phenomena are comparable to the sedimentological behaviors observed in other South Asian rivers as detailed by Sefein et al. [19], and further support the notion of high-energy fluvial environments capable of altering their depositional settings.

Braided River Environment and Proximal Source Influence

The dominance of coarse sedimentary materials and the presence of multiple channel systems are indicative of a braided river environment, a feature that is prominent in regions close to sediment sources [16]. This finding is consistent with the sediment transport mechanisms and depositional patterns outlined by Fahrudin et al. [11], which emphasize the geological complexity and the influence of tectonic settings as described by Pulunggono et al. [9].

Comparative Analysis and Global Perspectives

Drawing on comparative analyses with other geological studies, such as those by Hartanto et al. [12] on hydrocarbon prospects and by Longman and Beddoes [13] on Miocene carbonate platforms, the sedimentological characteristics of the Kikim Formation provide valuable insights into potential hydrocarbon reservoirs. These comparisons not only contextualize the Kikim Formation within a global framework but also highlight its potential for future resource exploration, echoing findings by Ghazi and Mountney [3].

Hydrocarbon Exploration and Geological Conservation

The detailed sedimentological analysis has direct implications for hydrocarbon exploration within the South Sumatra Basin, particularly in identifying potential reservoirs as highlighted by Jazuli et al. [10]. Furthermore, the environmental and geological conservation aspects, as discussed by Kirellos et al. [20], underscore the importance of sustainable practices in geological investigations, ensuring that valuable geological and ecological features are preserved for future research and educational endeavors.

Advancements in geological research methodologies, as discussed by various authors [4, 8, 14, 15, 17, 18, 21], offer new tools and approaches for detailed sub-surface analysis, enhancing our understanding of depositional environments and aiding in the more accurate prediction of hydrocarbon reservoirs. The integration of these methodologies can lead to more effective exploration strategies and better management of geological resources.

6. Conclusion

This study has systematically analyzed the conglomerate and sandstone deposits of the Kikim Formation, offering profound insights into the depositional dynamics and architectural elements of a fluvial environment within the South Palembang Subbasin. The investigation revealed a complex interplay of lithofacies, each marking distinct sedimentological processes shaped by both autogenic and allogenic factors.

- ✓ **Diversity of Lithofacies**: The identification of ten distinct lithofacies, ranging from gravel matrix-supported massive (Gmg) to carbonaceous mud (C), highlights the heterogeneity of the depositional environment. These facies indicate varying energy levels and sediment transport mechanisms, with coarser materials deposited via high-energy debris flows and finer sediments settling in quieter, lower-energy settings.

- ✓ **Channel Dynamics and Architectural Elements**: The study delineated four primary architectural elements—Gravel Bars (GB), Sandy Bedforms (SB), Channels (CH), and Floodplains (FF). Each element is reflective of specific fluvial processes, from the irregular transport dynamics in gravel bars to the stable sedimentation in floodplains. These findings align with the facies analysis models proposed by Miall [5], enhancing our understanding of fluvial deposition in braided river systems.

- ✓ **Braided River Environment**: The dominance of coarse sedimentary materials and the presence of multi-channel systems corroborate the braided river model as the primary fluvial architecture. This environment is characterized by high sediment loads and rapid depositional rates, which are conducive to the formation of extensive gravel bars and sandy bedforms.

- ✓ **Implications for Resource Exploration**: The sedimentological characteristics defined in this study have direct implications for hydrocarbon exploration within the South Sumatra Basin. The detailed mapping of lithofacies and understanding of depositional environments aid in predicting potential hydrocarbon reservoirs, guiding exploration strategies.

- ✓ **Future Research and Conservation**: This research underscores the importance of integrating detailed field data with advanced geological modeling techniques to enhance the predictive accuracy of sedimentological studies. Future studies should focus on longitudinal comparisons within the basin to refine depositional models further. Additionally, the conservation of these geological features is crucial, ensuring that they remain invaluable resources for educational and research purposes.

By thoroughly investigating the lithofacies and architectural elements of the Kikim Formation, this study contributes significantly to the geological understanding of the South Palembang Subbasin. It provides a robust framework for future geological and resource management endeavors in similar sedimentary environments.

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References

[1] A. J. Barber, M. J. Crow, and J. S. Milsom, *Sumatra: Geology, Resources and Tectonic Evolution*. London: The Geological Society, 2005.

[2] M. G. Bishop, "South Sumatra Basin Province, Indonesia: The Lahat/Talang Akar Cenozoic Total Petroleum System," U.S. Geological Survey, Colorado, 22 hours, 2001.

[3] M. Djuhaeni dan, *Sandi Stratigrafi Indonesia*, Komisi Sandi Stratigrafi Indonesia, Ikatan Ahli Geologi Indonesia, 1996.

[4] S. Ghazi and N. P. Mountney, "Facies and architectural element analysis of a meandering fluvial succession: The Permian Warchha Sandstone, Salt Range, Pakistan," *Sedimentary Geology*, vol. 221, no. 1-4, pp. 99–126, 2009, doi: 10.1016/j.sedgeo.2009.08.002.

[5] A. D. Miall, "Lithofacies Type And Vertical Profile Models In Braided River Deposits: a summary," in *Fluvial sedimentology*, Canadian Society Petroleum Geology Memoirs 5, pp. 597-604, 1978.

[6] A. D. Miall, "Architectural-element analysis: a new method of facies analysis applied to fluvial deposits," *Earth Science Rev*, vol. 22, pp. 261-308, 1985.

[7] A. D. Miall, *The Geology of Fluvial Deposits: Sedimentary Facies, Basin Analysis and Petroleum Geology*. New York: Springer, 1996.

[8] A. Pulunggono et al., "Pre-Tertiary and Tertiary Fault Systems as a Framework of The South Sumatra Basin; A Study of SAR-Maps," *Proceedings of the Indonesian Petroleum Association 21st Annual Convention and Exhibition*, pp. 339-360, 1992.

[9] A. Pulunggono, "Sumatran microplates, their characteristics and their role in the evolution of the Central and South Sumatra Basin," *Proc. of the 13th IPA Annual Convention*, Jakarta, May 1984.

[10] R. Ryacudu, "Tinjauan Stratigrafi Paleogen Cekungan Sumatra Selatan," *Indonesian Association of Geologist: Sumatra Stratigraphy Workshop*, Bandung: Institut Teknologi Bandung, pp. 99-114, 2008.

[11] U. K. G. Susilo and B. K., "Facies and Architectural Element Analysis of Braided Fluvial Succession: The Tertiary Sawah tambang Sandstone, Sawahlunto, Indonesia," *Journal of Physics: Conference Series*, 2019, doi: 10.1088/1742-6596/1363/1/012035.

[12] Munasri and A. Maharsha Putra, "First evidence of Middle to Late Triassic radiolarians in the Garba mountains, South Sumatra, Indonesia," *Island Arc*, vol. 28, 2019, doi: 10.1111/iar.12298.

[13] R. Irzon et al., "Wackestones and Grainstones Geochemistry from Baturaja Formation, South Sumatra Province, Indonesia: Origin and Depositional Environment," *Sains Malaysiana*, 2022, doi: 10.17576/jsm-2022-5104-05.

[14] S. K. Daryono et al., "Facies and architectural analysis of Paleogen fluvial deposits of the measured section of Rambangnia and Air Napalan Rivers in Palembang Sub-basin," *Journal of Earth and Marine Technology (JEMT)*, vol. 3, no. 1, 2022, doi: 10.31284/j.jemt.2022.v3i1.3606.

[15] J. Li et al., "Paleogene carbonate microfacies and sandstone provenance (Gamba area, South Tibet): Stratigraphic response to initial India–Asia continental collision," *Journal of Asian Earth Sciences*, vol. 104, pp. 39-54, 2015, doi: 10.1016/J.JSEAES.2014.10.027.

[16] K. Hartanto, E. D. Widianto, and Safrizal, "Hydrocarbon Prospect Related to the Local Unconformities of the Kuang Area, South Sumatra Basin," 1991, doi: 10.29118/ipa.1714.17.35.

[17] F. Fahrudin et al., "Tectonostratigraphic analysis and depositional pattern of South Palembang sub-basin, South Sumatra Basin," 2021, doi: 10.1063/1.5062720.

[18] N. Suwarna and Y. Kusumahbrata, "Macroscopic, Microscopic, and Paleo-depositional Features of selected Coals in Arahan, Banjarsari, Subanjeriji, and South Banko Regions, South Sumatra," *Indonesian Journal on Geoscience*, vol. 5, pp. 269-290, 2010, doi: 10.17014/ijog.5.4.269-290.

[19] R. Fakhruddin et al., "Facies analysis and palynology of upper Miocene to Pliocene sediments exposed at Timika–Tembagapura section, Papua, Indonesia," *Australian Journal of Earth Sciences*, vol. 68, pp. 213-228, 2021, doi: 10.1080/08120099.2020.1767205.

[20] M. Longman and J. Beddoes, "Oil-Productive Miocene Algal and Sea Grass Carbonate Mudbanks, South Sumatra, Indonesia: ABSTRACT," *AAPG Bulletin*, vol. 69, 1985, doi: 10.1306/AD462132-16F7-11D7-8645000102C1865D.

[21] K. J. Sefein, T. X. Nguyen, and R. P. Philp, "Organic geochemical and paleoenvironmental characterization of the Brown Shale Formation, Kiliran sub-basin, Central Sumatra Basin,

Indonesia," *Organic Geochemistry*, vol. 112, pp. 137-157, 2017, doi: 10.1016/J.ORGGEOCHEM.2017.06.017.