Sedimentary facies and depositional environments of the Halang Formation in the North Serayu Basin: Insights from outcrop study in Bantarbolang, Pemalang, Central Java.

Antu Ridha Falkhan Barizi[1], Carolus Prasetyadi[1], Miftakhuddin Amir Slamet Janukusuma[1], M. Nurjati Setiawan[1]

[1]Pusat Studi Mineral dan Energi (PSME) UPN "Veteran" Yogyakarta, Yogyakarta, Indonesia

Corresponding author: falkhan@geodin.net

ABSTRACT

Halang Formation has been the subject of extensive research due to its unique characteristics, particularly its turbidite facies, which indicate deposition in deep marine environments. Previous studies have revealed a complex lithological composition, including sandstone, calcareous sandstone, claystone, marl, tuff, and breccia, with an upward coarsening pattern indicative of progradation processes. The presence of Bouma's sequence further confirms the dominance of turbidite deposits within the formation. This research aims to define the depositional environment of the Halang Formation through detailed lithofacies and microfossil analyses, focusing on a previously understudied area in the North Serayu Basin. By integrating data from field observations and micropaleontological analysis, this study seeks to provide valuable insights into the sedimentary processes and paleoenvironments that formed the Halang Formation. Our findings indicate that the formation was deposited in a submarine fan environment, specifically in the smooth portion of suprafan lobes, which are characterized by dominant classical turbidite (CT) facies. Micropaleontological analysis suggests an inner to outer bathyal environment at depths ranging from 283.65 to 713.7 meters. These results contribute to our understanding of the Halang Formation depositional history and the broader geological evolution of the North Serayu Basin.

Keywords: *Halang Formation, North Serayu Basin, turbidite deposits, submarine fan*

Copyright ©2024 by Author, published by FOSI. Author doesn't retain all rights. This is an open access article distributed under Creative Commons license (CC-BY-SA 4.0).

Manuscript received: 17 Feb 2024, revised manuscript received: 07 Jul 2024, final acceptance: 26 Jul 2024. DOI: 10.51835/bsed.2024.50.1.447

INTRODUCTION

Previous research on the Halang Formation has extensively discussed its characteristics, particularly its turbidite facies indicative of deposition in deep marine environments extending up to the upper bathyal zone. Comprised of interbedded lithologies including sandstone, calcareous sandstone, claystone, marl, tuff, and breccia, the Halang Formation exhibits an upward coarsening pattern suggestive of progradation processes (Asikin *et al.*, 1992; Armandita, Mukti and Satyana, 2009; Mukti and Ito, 2010; Praptisih and Kamtono, 2011). Turbidite deposits are a prominent feature of the Halang Formation succession, characterized by interbedded sandstone and claystone layers exhibiting Bouma's sequences, denoted by small-scale coarsening upward intervals (±10 cm) identified as Ta, Tb, Tc, Td, and Te (Bouma, 1962). This facies classification is used for classical turbidite deposit types, which indicate low-density turbidite currents (Shanmugam, 2000). This facies pattern serves as a valuable indicator of the depositional environment, with finer-grained lithologies such as claystone dominating further from the deposition source and coarser-grained lithologies like sandstone dominating closer to the source.

This research aims to define the depositional environment of the Halang Formation through a comprehensive analysis of lithofacies and microfossils. The study area, located in the North Serayu Basin, presents an intriguing opportunity as the Halang Formation in

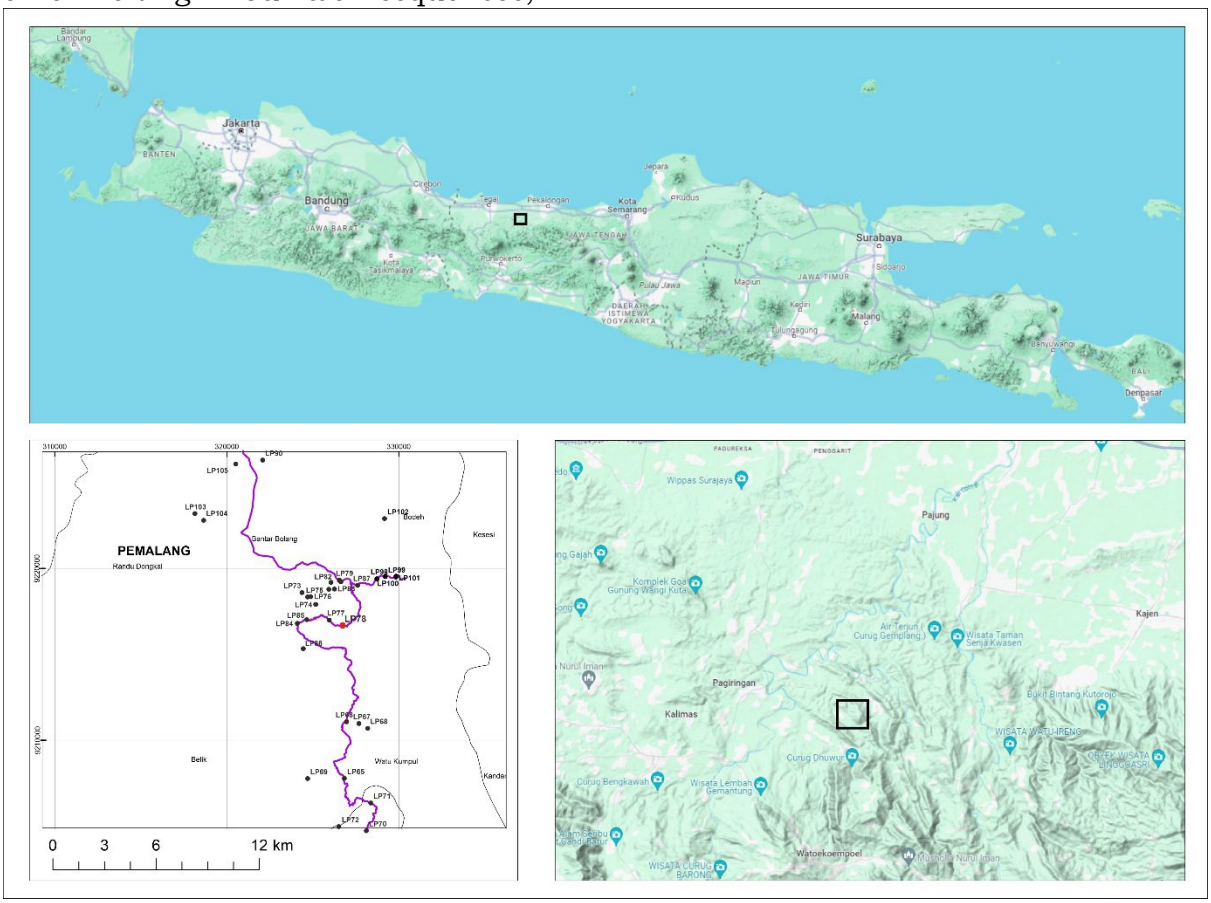


Figure 1. *Research locations located in Bantarbolang District, Pemalang, Central Java*

this region has not been extensively investigated. The primary objective is to verify whether the Halang Formation in the research area was deposited in a submarine fan within a deep marine environment. Given the lack of thorough research in this specific location, there is a lingering concern that the depositional environment of the Halang Formation here may differ from that of other areas, such as Banyumas or West Java. By conducting detailed lithofacies and microfossil analyses, this study seeks to provide valuable insights into the depositional processes and paleoenvironmental conditions that shaped the Halang Formation in the North Serayu Basin. Such findings would not only enhance our understanding of regional geological history but also contribute to broader discussions on sedimentary basin evolution and paleoenvironmental reconstructions.

GEOLOGICAL SETTING

Tectonic setting of North Serayu Basin

The North Serayu Zone has comparatively simpler physiography than the South Serayu Zone but stands as a pivotal geological feature shaping the landscape of Central Java It is characterized by a single east-west mountain range with a sweeping curve that opens towards the south, with both ends occupied by Quaternary volcanoes, marking both its geographical extent and its dynamic geological history (Husein *et al.*, 2013). Situated within the deep marine zone of the Bogor-North Serayu Kendeng, the North Serayu Basin is positioned as a back-arc basin in relation to the Oligo-Miocene volcanic arc that stretches across the southern reaches of Java Island (Satyana and Armandita, 2004). This strategic location offers a unique window into the tectonic and volcanic processes that have shaped the region over millions of years.

During the Late Oligocene and Early Miocene periods, the North Serayu Basin experienced significant geological activity, including the development of a volcanic arc within the Southern Serayu Zone. This period saw the basin filled with carbonate sandstone, conglomerates, and interbedded shale, marl, and tuff, forming what is known as the Rambatan Formation (Hall, 2012; Husein *et al.*, 2013). The sedimentary processes during this time were driven by the gravitational forces associated with the evolving volcanic arc, resulting in distinctive sedimentary structures and lithologies that provide valuable insights into the basin's depositional history and tectonic evolution.

As the geological timeline progresses into the Late Miocene and beyond, the North Serayu Basin continues to be shaped by volcanic activity, with volcanism spreading across the region and contributing to further geological transformations. This period of intense volcanic activity not only influenced the landscape but also had profound effects on sedimentation patterns and basin dynamics, leading to significant uplift and gravitational spreading events (Van Bemmelen, 1949). Through detailed geological investigations and analysis of sedimentary records, researchers continue to unravel the complex interplay of tectonic forces and volcanic activity that have sculpted the North Serayu Basin into the geological marvel it is today.

Regional stratigraphy

Regional stratigraphy and tectonic deformation between the North and South Serayu Zones are interconnected (Figure 2). The South Serayu Zone contains pre-Tertiary and Paleogene rocks exposed at the surface in Karangsambung, such as the Luk-Ulo Complex with Late Cretaceous age, Karangsambung Formation, and Totogan Formation with Paleogene age. These formations were formed due to deep-sea gravitational landslide processes post-collision between Sundaland and the microcontinental plate of East Java (Hall, 2012). Within the Luk-Ulo Complex and Karangsambung Formation, there was a transition in sedimentation from matrix-dominated to more fragment-dominated within the Totogan Formation (Asikin *et al.*, 1992). This indicates that the depositional environment experienced heavy subsidence, and the uplift of Karangsambung became stronger during the Late Paleogene (Prasetyadi, 2007).

Halang Formation consisted mainly of turbidite deposits, which are sedimentary rocks formed by underwater avalanches carrying eroded materials. These deposits can be divided into three main rock units:

Breccia-sandstone unit: Proximal facies, likely representing the closest area to the source of the material.

Sandstone-claystone unit: Medial facies, deposited further away from the source.

Siltstone-claystone unit: Distal facies, located farthest from the source and containing finer-grained sediments.

Generally considered to be formed in a deep-sea submarine fan system, with different facies representing different parts of the fan (slope, inner fan, middle fan, outer fan). However, recent research

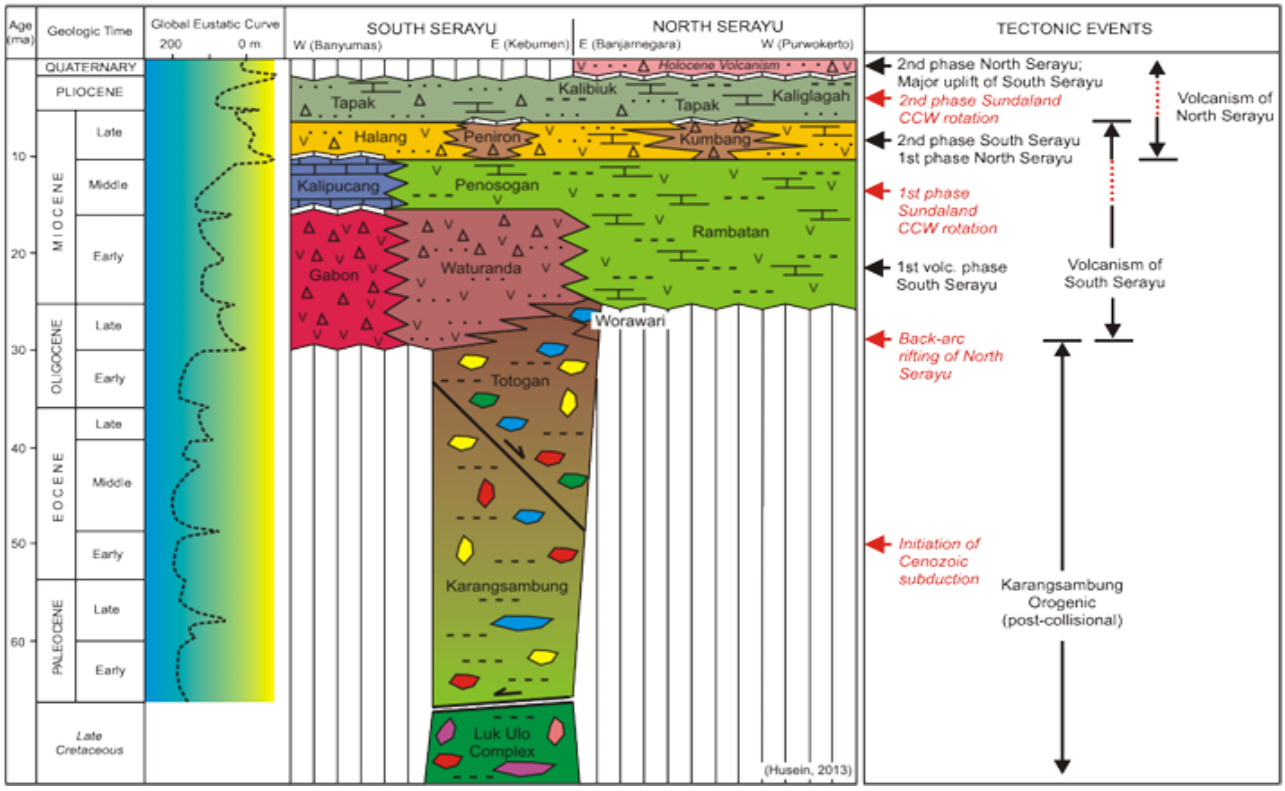


Figure 2. *Cenozoic tectonostratigraphy of the Serayu Zone (Husein et al., 2013)*

suggests there might be more complexity, with evidence pointing towards potential shallower water deposition in some areas.

DATA AND METHODS

This research consists of two stages: data collection and data analysis. The data collection stage includes a literature review and field observation. Field observation involves the observation and description of rock outcrops, sedimentary logging, sampling, and documentation. The data analysis stage includes the facies analysis of sedimentary log outcrop profiles and micropaleontological analysis.

The analysis of outcrop profiles is used to determine the facies and depositional environment of the research location based on the interpretation and identification of lithofacies. The identification of facies and depositional environments utilizes two models: the turbidite model (Bouma, 1962) and the submarine fan model (Walker, 1978). Micropaleontological analysis is employed to determine the age and bathymetric zone of the research location based on the Blow zonation (1969). There are two types of foraminifera: planktonic foraminifera used to determine the age of the rocks, and benthic foraminifera used to determine the bathymetric zones.

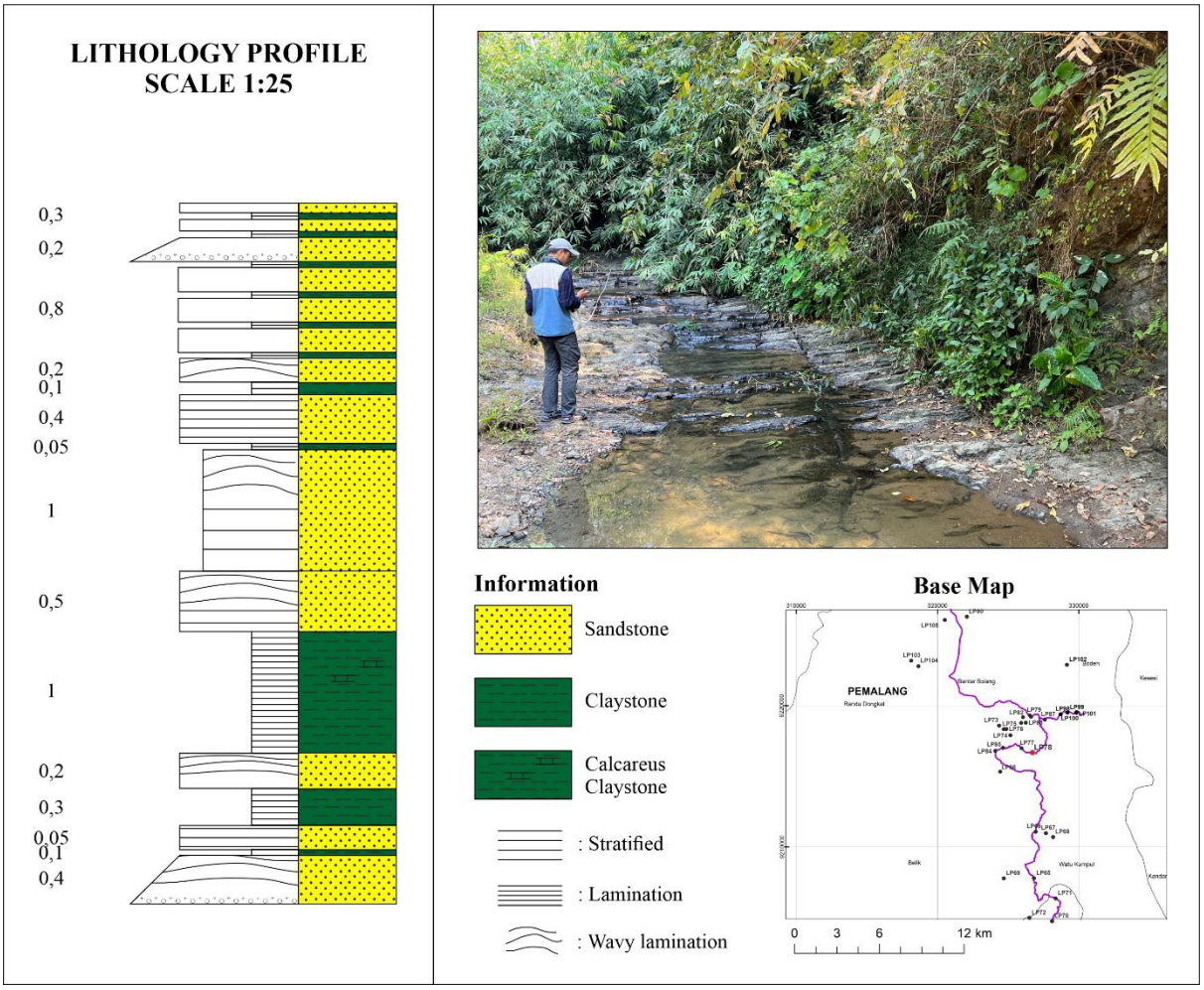


Figure 3. *Sedimentary log profile for one of the outcrops observed in the study.*

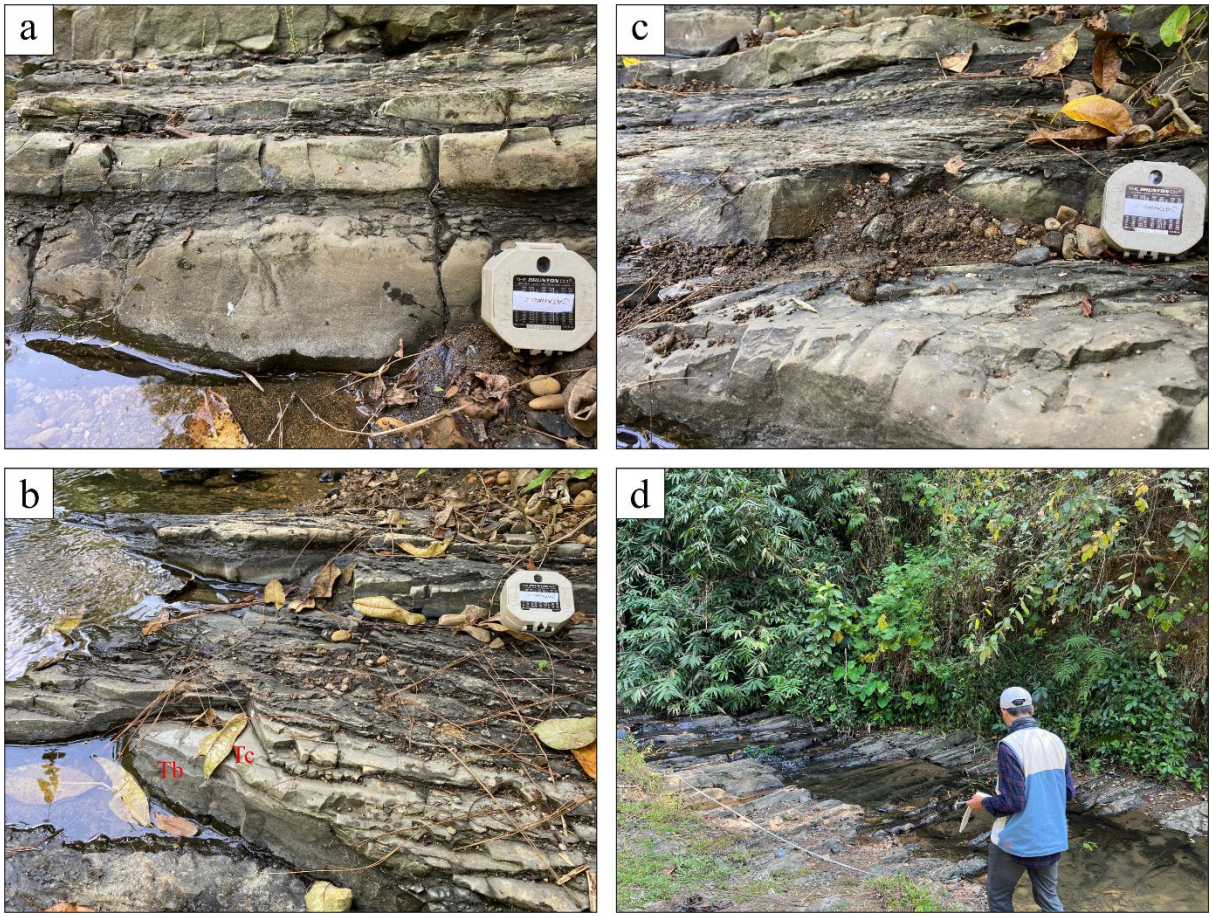


Figure 4. *(a) sandstone with a graded bedding structure (Ta), (b) sandstone with a laminated and wavy laminated structure (Tb and Tc), (c) claystone with a laminated structure (Td), and (d) interbedded sandstone – claystone indicates classical turbidite (CT) facies.*

RESULTS AND INTERPRETATION

The outcrop observation is conducted to examine the general depositional succession. The outcrop displays interbedding between sandstone and claystone layers, with occasional insertions of calcareous claystone. A sedimentary log profile is then created along the approximately 5-meter outcrop length to visualize the field observations for further detailed identification of turbidite facies.

Bouma's turbidite model

This concept applied to each individual distinctive sequence pattern observed in the rock layers. In the research area, a sequence pattern of Ta, Tb, Tc, and Td is observed (Figure 4a, 4b, and 4c), with the dominant sequence pattern being the recurring pattern of Tb-Tc (Figure 3). The Ta interval consists of coarse sand-sized sandstone lithology (0.25 - 0.5 mm) with a graded bedding structure. This structure shows a fining upward pattern due to gravity, which then transitions into the Tb interval. The Tb interval consists of fine sand-sized sandstone lithology (0.125 - 0.25 mm) with a laminated structure and also exhibits ripple lamination. The Tc interval consists of sandstone lithology with a ripple lamination structure. The Td interval consists of claystone lithology with a laminated structure.

No	Depositional Enviroment		Transition	Neritic			Bathyal		Abyssal	Hadal
	Benthos Foraminifera Species	Amnt		Inner	Middle	Outer	Inner	Outer		
			0	20	100	200	500		2000	4000
1	*Globulina minuta (283,65 m)*	R					●			
2	*Orbulina universa (713,7 m)*	R						●		

Table 1. *Bentonic Foraminifera analysis results to determine the bathymetric zone*

Walker's submarine fan model

The presence of sedimentary structures such as graded bedding and lamination, influenced by turbidity currents, allows the Bouma sequence to be identified from intervals Ta-Td (Figure 2). These sequences fall within the classical turbidite (CT) facies. The facies are composed of lithologies with fine grain sizes. In the research area, there is interbedding between sandstone and claystone lithologies (Figure 4d). The sedimentary log profile shows a coarsening upward pattern and slow hemipelagic deposition. In this concept, changes in sea level are not clearly distinguishable.

Depositional Age and Bathymetric Zone

Micropaleontological analysis is conducted to determine the age and bathymetric zone of the Halang Formation outcrop samples. From the analysis that has been conducted, two benthic foraminifera samples were found: *Globolina minuta* and *Orbulina universa*. These fossils indicate that the bathymetric zone of the Halang Formation in the research area is in the inner to outer bathyal zone, at a depth of 283.65 - 713.7 meters (Table 1). Meanwhile, for age determination, four types of planktonic foraminifera were found: *Globigerina riveroae*, *Sphaeroidinella subdehiscens*, *Globigerinoides trilobus (*Editor's note: *Trilobatus trilobus)*, and *Orbulina universa*. These fossils have an age range from N18 to N19, corresponding to the Early Pliocene (Table 2).

Depositional environment

The identification of lithological profiles reveals a dominant Bouma sequence pattern, which constitutes classical turbidite (CT) with lithologies consisting of interbedding between fine-grained sandstone and claystone (Figure 5). Referring to the submarine fan model by Walker (1978), the Halang Formation in the research area are classified into the smooth portion of suprafan lobes in a submarine fan environment, supported by micropaleontological analysis results. The sedimentation process in the research area involves gravitational slumping caused by turbidity currents. These currents trigger submarine landslides, resulting in the formation of channels that gradually evolve into submarine fans. The

No	Age		Eocene					Oligocene					Miocene													Pliocene			Pleistocene		
	Plankton Foraminifera Species	Amnt	P13	P14	P15	P16	P17	P18	P19	P20 N1	P21 N2	P22 N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	N13	N14	N15	N16	N17	N18	N19	N20	N21	N22	N23
1	*Globigerina riveroae*	R																									■	■				
2	*Sphaeroidinella subdehiscens*	R																				■	■	■	■	■	■	■				
3	*Globigerinoides trilobus*	R													■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
4	*Orbulina universa*	R																■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Table 2. *Planktonic foraminifera analysis results to determine the age of the simples.*

landslides occur continuously, eventually forming submarine fans.

Additionally, these landslides contribute to the carbonate characteristics found in the rocks of the research area, which are interpreted to originate from shallow marine environments.

CONCLUSIONS

The findings from the analysis yield insightful conclusions regarding the depositional environment of the Halang Formation in Bantarbolang District, Pemalang, Central Java. This formation is deposited in a submarine fan environment, specifically the smooth portion of suprafan lobes characterized by classical turbidite (CT) facies suggested by the presence of Ta, Tb, Tc, and Td sequences in the succession of interbedding between sandstone and mudstone lithologies. Moreover, micropaleontological analysis supports this conclusion by indicating an inner to outer bathyal environment at depths ranging from 283.65 to 713.7 meters. The sedimentation process, driven by gravitational slumping triggered by turbidity currents, underscores the intricate interplay of geological forces that have sculpted the submarine fan over time. These insights may enhance our understanding of the Halang Formation especially in the North Serayu Basin.

ACKNOWLEDGEMENT

We extend our gratitude to Pertamina Upstream Research and Technology Innovation (URTI) for providing funding for this study.

REFERENCES

Armandita, C., Mukti, M. M. and Satyana, A. H., 2009. 'Intra-arc trans-tension duplex of Majalengka to Banyumas Area: prolific petroleum seeps and opportunities in West-Central Java border'. *Proceedings of IPA 33rd Annual Convention*. Indonesian Petroleum Association.

Asikin, S. *et al.,* 1992. *Peta Geologi Lembar Banyumas, Jawa, skala 1: 100.000*. Pusat Penelitian dan Pengembangan Geologi, Bandung.

Bouma, A. H., 1962. 'Sedimentology of some flysch deposits', *Agraphic approach to facies interpretation*, 168.

Hall, R., 2012. 'Late Jurassic–Cenozoic reconstructions of the Indonesian region and the Indian Ocean', *Tectonophysics*, 570–571, pp. 1–41. doi: https://doi.org/10.1016/j.tecto.2012.04.021.

Husein, S. *et al.,* 2013. 'Kendali stratigrafi dan struktur gravitasi pada rembesan hidrokarbon Sijenggung, Cekungan Serayu Utara', in *Prosiding Seminar Nasional Kebumian ke-6 Jurusan Teknik Geologi Fakultas Teknik Universitas Gadjah Mada, Yogyakarta*, pp. 474–489.

Mukti, M. M. and Ito, M., 2010. 'Discovery of outcrop-scale fine-grained sediment waves in the lower Halang Formation, an upper Miocene submarine-fan succession in West Java', *Sedimentary Geology*, 231(3–4), pp. 55–62.

Praptisih, P. and Kamtono, K., 2011. 'Turbidite Facies of the Halang Formation in Ajibarang Area, Central Java', *Indonesian Journal on Geoscience*, 6(1), pp. 13–27.

Prasetyadi, C., 2007. *Evolusi tektonik Paleogen Jawa bagian timur*. Doctoral Dissertation, Institut Teknologi Bandung.

Satyana, A. H. and Armandita, C., 2004. 'Deepwater plays of Java, Indonesia: Regional evaluation on opportunities and risks', in *IPA-AAPG Deepwater and Frontier Symposium*, pp. 293–319.

Shanmugam, G., 2000. '50 years of the turbidite paradigm (1950s—1990s): deep-water processes and facies models—a critical perspective', *Marine and Petroleum Geology*, 17(2), pp. 285–342.

Walker, R. G., 1978. 'Deep-Water Sandstone Facies and Ancient Submarine Fans: Models for Exploration for Stratigraphic Traps', *AAPG Bulletin*, 62(6), pp. 932–966. doi: 10.1306/C1EA4F77-16C9-11D7-8645000102C1865D.