

Calcareous Nannofossils from Bojongsana River, Purbalingga Regency: Implication for Identifying the Age of Tapak Formation

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Manuscript received: 27 March 2026; Received in revised form: 19 June 2026; Accepted: 14 July 2026

Abstract

Calcareous nannofossils are widely used in Cenozoic biostratigraphy due to their rapid evolution and wide geographic distribution. Their biostratigraphic significance provides a useful basis for resolving age uncertainties in sedimentary successions. In this context, the lower Tapak Formation exposed along the Bojongsana River section in the Banyumas Basin, Central Java, represents an important stratigraphic unit whose depositional age remains poorly constrained. This study aims to determine the depositional age of the lower Tapak Formation using calcareous nannofossil biostratigraphy. A 61 m-thick stratigraphic section was systematically measured, and 24 samples were collected at 2–5 m intervals for analysis. The nannofossil assemblages showed moderate to good preservation, with abundances ranging from rare to abundant. A total of 24 nannofossil species from 10 genera were identified. Biostratigraphic analysis revealed two partial distribution zones: the *Discoaster berggrenii* Zone (CNM17) and the *Nicklithus amplificus* Zone (CNM18), indicating a Late Miocene age (equivalent to zone NN11). The First Occurrence (FO) of *Nicklithus amplificus* was used to define the lower boundary of the CNM18 zone, whereas the upper boundary could not be determined because no additional biodatum or bioevent was recorded in the upper part of the section. Reworked taxa indicate sediment input from older Middle Miocene units but do not affect age interpretation. This finding demonstrates that the lower Tapak Formation in the Bojongsana River section represents a Late Miocene interval. Stratigraphically constrained biostratigraphic data are therefore essential for refining the regional chronostratigraphic framework of the Banyumas Basin.

Keywords: Banyumas Basin; Late Miocene; Nannofossils; Tapak Formation.

Citation: Akmaluddin, A., & Nurhidayah, E. M. (2026). Calcareous Nannofossils from Bojongsana River, Purbalingga Regency: Implication for Identifying the Age of Tapak Formation. *Jurnal Geoelebes*, 10(2): 258–268, doi: 10.70561/geoelebes.v10i2.50394

Introduction

Calcareous nannofossils are a group of unicellular marine phytoplankton that are highly abundant and widely distributed, both in the geological past and in modern oceans (Balch, 2018; Gastaldello et al., 2023; Karatsolis et al., 2026), and their application has also been widely implemented in various sedimentary basins in Indonesia (Rendy et al., 2021; Supardi & Rahmawati, 2022; Ratumanan et al., 2023; Nurhidayah et al., 2024; Choiriah et al.,

2025). Calcareous nannofossils represent the principal microfossil groups used in Cenozoic marine biostratigraphic studies (Agnini et al., 2014; 2017; Puentes-Jorge et al., 2025). These characteristics make them particularly useful for improving the resolution and consistency of stratigraphic interpretation (Raffi & Backman, 2022).

The Banyumas Basin, located in Central Java, is considered a Neogene sedimentary basin with hydrocarbon potential and records complex interactions between

tectonics, sedimentation, and sea-level changes (Purwasatriya et al., 2019; Permana et al., 2024). One of its key stratigraphic units, the Tapak Formation, has been widely studied, including its potential as a hydrocarbon reservoir (Rizal et al., 2018; Tampubolon & Rizal, 2019). The Tapak Formation is generally characterised by clastic marine deposits, including interbedded coarse sandstone and marl, greenish sand, conglomerate and andesitic breccia (Tampubolon & Rizal, 2019). Establishing a reliable depositional age for this formation is therefore essential for refining its stratigraphic position and improving regional correlations within the basin.

Previous studies have attempted to constrain the age of the Tapak Formation using planktonic and benthic foraminifera, suggesting an Early to Late Pliocene age, corresponding to zones N18–N21 (Novandaru et al., 2025). Meanwhile,

calcareous nannofossil studies from other parts of the basin indicate an Early Pliocene age based on zones NN14–NN15 (Dwijaya et al., 2021). Although these studies provide valuable biostratigraphic information, calcareous nannofossil data from the lower Tapak Formation in the Bojongsana River section remain limited. Given this limitation, calcareous nannofossil analysis from a systematically measured stratigraphic section is needed to provide additional biostratigraphic evidence for the lower Tapak Formation and to refine the Neogene chronostratigraphic framework of the Banyumas Basin (Wolfgring et al., 2026).

In the Bojongsana River section, which represents the outcrop marine sediment of the lower Tapak Formation (Djuri et al., 1996) (Figure 1), the depositional age has not yet been evaluated using a stratigraphically constrained nannofossil approach.

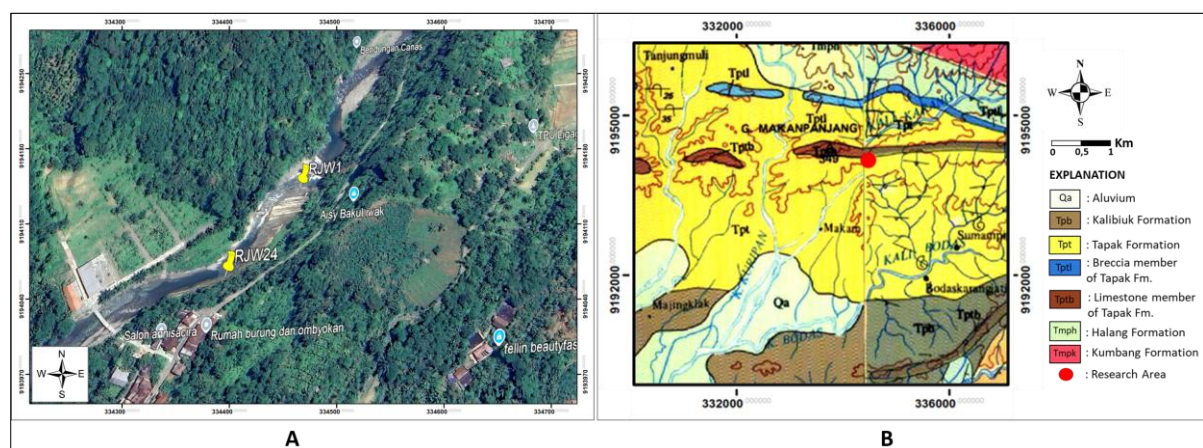


Figure 1. Location of the research area along the Bojongsana River, Purbalingga Regency, Central Java. (A) Google Earth satellite image (2026) showing the measured stratigraphic section and sampling points. (B) Regional geological map of the Purwokerto–Tegal (Djuri et al., 1996) sheets, with the research area marked by a red dot within the Tapak Formation.

To address this issue, this study applies calcareous nannofossil biostratigraphy to a systematically measured stratigraphic section in the Bojongsana River area. This study aims to establish the depositional age of the lower Tapak Formation and to provide a more consistent age interpretation by integrating nannofossil data within a well-constrained stratigraphic framework. The results are expected to improve the

chronostratigraphic framework of the Tapak Formation and contribute to a better understanding of basin evolution in the Banyumas Basin.

Regional Geology

Physiographically, the Banyumas Basin is subdivided into the South Serayu and North Serayu Zones (Husein et al., 2013). The tectonic framework of the region was

established by Cenozoic subduction along the southern margin of Java. This tectonic evolution also controlled the present basin architecture, in which the Banyumas Basin is subdivided into the Majenang and Citanduy sub-basins, separated by the Cipari Anticline (Hidayat et al., 2020), and is characterised by northwest–southeast strike-slip faults and east–west basement highs (Setiadi, 2017).

Stratigraphically, the Banyumas Basin in the North Serayu Zone begins with the Rambatan Formation (Figure 2). The Rambatan Formation was deposited during

the N13–N19 interval in a deep-marine setting (Astuti et al., 2019). Above it, the Halang Formation, deposited in the Late Miocene to Early Pliocene (Adam et al., 2025), is composed primarily of marl and turbiditic sandstone (Purwasatriya et al., 2021). The Tapak Formation, deposited during the Pliocene (Djuri et al., 1996). This unit comprises calcareous sandstone, calcarenite, and marl, with abundant shallow-marine fossils. Stratigraphically, the Tapak Formation lies conformably above the Halang Formation and reflects a shift in depositional environment toward shallower (Rohmana et al., 2019).

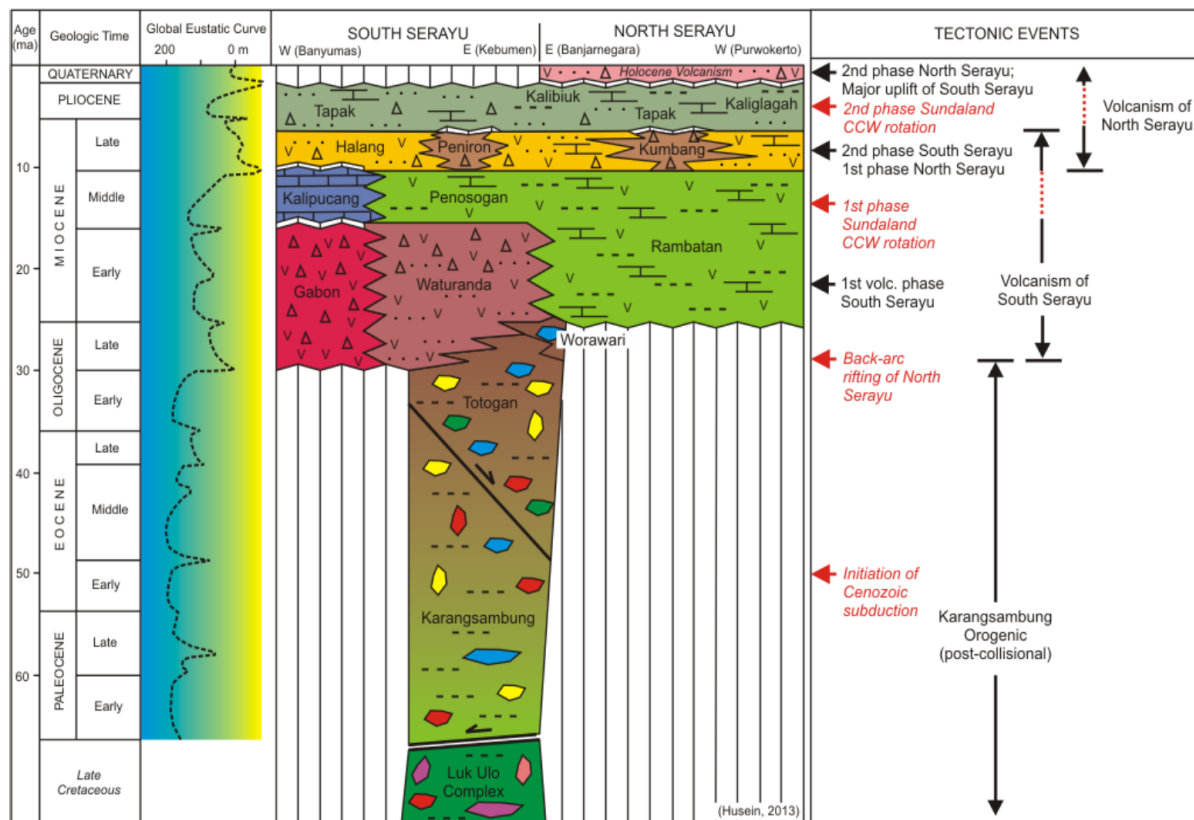


Figure 2. Cenozoic tectonostratigraphy of the Serayu Zone (Husein et al., 2013).

Materials and Methods

Data collection was conducted using stratigraphic measurements and systematic rock sampling. In this study, a 61 m thick stratigraphic section was measured in the Bojongsana River area, Purbalingga Regency, Central Java. A total of 24 samples were collected at 2–5 m intervals for calcareous nannofossil analysis (Figure 3).

Calcareous nannofossil slide preparation was conducted using the drop technique, producing smear slides suitable for microscopic examination. This modification allowed an even distribution of sediment on the coverslip without additional dilution steps.



Figure 3. Outcrop of the Tapak Formation exposed along the Bojongsana River, Purbalingga Regency, Central Java Province. Numbers 1–4 indicate representative nannofossil sampling points.

Species abundance was assessed semi-quantitatively following, using the following categories: A (abundant; >10 specimens per field of view), C (common; 2–10 specimens per field of view), F (few; 1 specimen per 1–5 fields of view), R (rare; 1 specimen per 6–10 fields of view), and VR (very rare; 1 specimen in >10 fields of view). Nannofossil identification was performed based on morphological criteria compiled in Nannotax3 (Young et al., 2023). Biostratigraphic zonation follows the standard scheme of Agnini et al. (2014) and is correlated with previous zonations by Okada & Bukry (1980) and Martini (1971).

The First Occurrence (FO) and Last Occurrence (LO) of marker nannofossil species also follow the latest geochronological framework (Agnini et al., 2017; Blair et al., 2017).

Results

Diversity and Systematic Taxonomy of Nannofossils

Nannofossil analysis of 24 samples indicates moderate to good preservation, with abundances ranging from rare to abundant. The nannofossils identified in the study area generally exhibit good preservation. Biodatum ages were determined using several established references, and detailed analysis identified 24 species across 10 genera. The taxonomic identification and nomenclature of all calcareous nannofossil species follow the Nannotax database (Young et al., 2023). A taxonomic summary of the identified species is presented in Table 1, and selected species from the Bojongsana River area are presented in Figure 4.

Table 1. Resume of the taxonomic ranks of calcareous nannofossil in research area.

Group	Order	Family	Genus	Species		
Heterococcoliths	Coccolithales	Coccolithaceae	<i>Coccolithus</i>	<i>Coccolithus pelagicus</i>		
		Calcidiscaceae	<i>Calcidiscus</i>	<i>Calcidiscus leptoporus</i>		
			<i>Umbilicosphaera</i>	<i>Umbilicosphaera jafari</i>		
			<i>Umbilicosphaera</i>	<i>Umbilicosphaera rotula</i>		
	Isochrysidales	Noelaerhabdaceae	<i>Cyclicargolithus</i>	<i>Cyclicargolithus floridanus</i>		
			<i>Reticulofenestra</i>	<i>Reticulofenestra haqii</i> (<i>Reticulofenestra pseudumbilicus</i> <i>Reticulofenestra rotaria</i>		
			Zygodiscales	Helicosphaeraceae	<i>Helicosphaera</i>	<i>Helicosphaera carteri</i> <i>Helicosphaera princei</i>
					Pontosphaeraceae	<i>Pontosphaera</i>
	Nannoliths	Discoasterales	Ceratolithaceae	<i>Amaurolithus</i>	<i>Nicklithus amplificus</i>	
			Discoastersceae	<i>Discoaster</i>	<i>Discoaster deflandrei</i> <i>Discoaster berggrenii</i> <i>Discoaster brouweri</i> <i>Discoaster calcaris</i> <i>Discoaster neorectus</i> <i>Discoaster pentaradiatus</i> <i>Discoaster musicus</i> <i>Discoaster quinquaramus</i> <i>Discoaster variabilis</i>	
Sphenolithaceae				<i>Sphenolithus</i>	<i>Sphenolithus abies</i> <i>Sphenolithus moriformis</i> <i>Sphenolithus neoabies</i>	

Biostratigraphy

Based on measured stratigraphic sections, the Tapak Formation outcrops show vertical lithological variations. The lower part consists mainly of thick, light grey, coarse-grained sandstone with parallel bedding. Towards the upper part of the section, the lithology becomes predominantly interbedded calcareous mudstone and sandstone (Figure 5).

A total of 24 nannofossil species were successfully identified (Figure 3 & 6), including several biostratigraphically significant taxa as biodatum, namely *Discoaster berggrenii* and *Nicklithus amplificus*. Based on the first and last occurrences of these taxa (Figure 3 & 5), the studied interval is subdivided into two biozones, arranged from oldest to youngest as follows:

1. *Discoaster berggrenii* Partial Range Zone (CNM17 zone)

The *Discoaster berggrenii* Zone (CNM17) is defined as a partial range zone marked by the first occurrence (FO) of *Nicklithus amplificus* in the upper part of the interval (sample RJW 18), while its lower boundary could not be determined because no diagnostic bioevent was recorded at the base of the studied interval.

This zone is assigned to the CNM17 zone of Agnini et al. (2014) and is broadly correlated with Zone NN11 of Martini (1971) and Zones CN9b of Okada & Bukry (1980). Chronostratigraphically, the interval is interpreted as Late Miocene in age and is recorded within the 0–50 m stratigraphic interval.

In addition, the occurrence of *Cyclicargolithus floridanus* within this interval is interpreted as a reworked fossil derived from Middle Miocene or older deposits. Therefore, this taxon is not used as an indicator of the depositional age of the lower Tapak Formation, but is interpreted as evidence of sediment input or erosion

from older stratigraphic units exposed in the source area.

2. *Nicklithus amplificus* Partial Range Zone (CNM18 zone or younger)

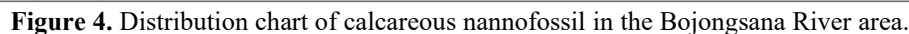
The *Nicklithus amplificus* Zone (CNM18 zone or younger) is a partial range zone. The base of the *Nicklithus amplificus* Zone is defined by the First Occurrence (FO) of *Nicklithus amplificus* in sample RJW 18, recorded at the 51 m stratigraphic interval. However, the upper boundary of this zone could not be determined because no additional biodatum or bioevent was recorded in the upper part of the studied section. Therefore, the interval from 51 to 60.5 m is tentatively assigned to CNM18 of Agnini et al. (2014), or possibly younger.

This interval is broadly comparable to the upper part of NN11 of Martini (1971) and approximately to CN9b of Okada & Bukry (1980). Chronostratigraphically, the occurrence of *N. amplificus* supports a Late Miocene age interpretation. The occurrences of *Discoaster deflandrei* and *Discoaster musicus* are interpreted as reworked material from older Middle Miocene to Late Miocene deposits and are therefore not used as primary indicators of depositional age.

Discussion

Biostratigraphic analysis of calcareous nannofossils from the lower Tapak Formation indicates a Late Miocene age for the studied section. This interpretation is supported not only by the recognition of the *Discoaster berggrenii* Zone (CNM17) and the *Nicklithus amplificus* Zone (CNM18) or younger of Agnini et al. (2014), which broadly correlate with the NN11 Zone of Martini (1971) and the CN9b interval of Okada & Bukry (1980), but also by the occurrence of other Late Miocene nannofossil taxa. These taxa include *Discoaster quinquedentatus*, *Discoaster calcaris*, *Reticulofenestra rotaria*, and *Discoaster neorectus*, which provide additional biostratigraphic support for the

stratigraphic units and do not affect the Late Miocene age interpretation of the studied interval.



Overall, the lower Tapak Formation in the Bojongsana River section is interpreted to have been deposited during the Late Miocene, while younger Pliocene ages reported from other sections may represent higher stratigraphic levels within the formation.

Based on calcareous nannofossil analysis, the Tapak Formation within the studied interval contains 24 species, with abundances ranging from rare to abundant, indicating deposition in an open-marine setting with favourable preservation conditions. Biostratigraphic evaluation establishes the *Discoaster berggrenii* zone (CNM17) and *Nicklithus amplificus* zone (CNM18), indicating a Late Miocene age. The boundary between these zones is defined by the First Occurrence (FO) of *Nicklithus amplificus*, which serves as a reliable datum for regional stratigraphic correlation.

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The authors gratefully acknowledge the Department of Geological Engineering, Faculty of Engineering, Universitas Gadjah Mada, for providing financial support for this research in FY 2025. The authors also

gratefully acknowledge Muhammad Rafly Siregar for his valuable assistance with the preparation of calcareous nannofossil samples at the Paleontology Laboratory, Universitas Gadjah Mada.

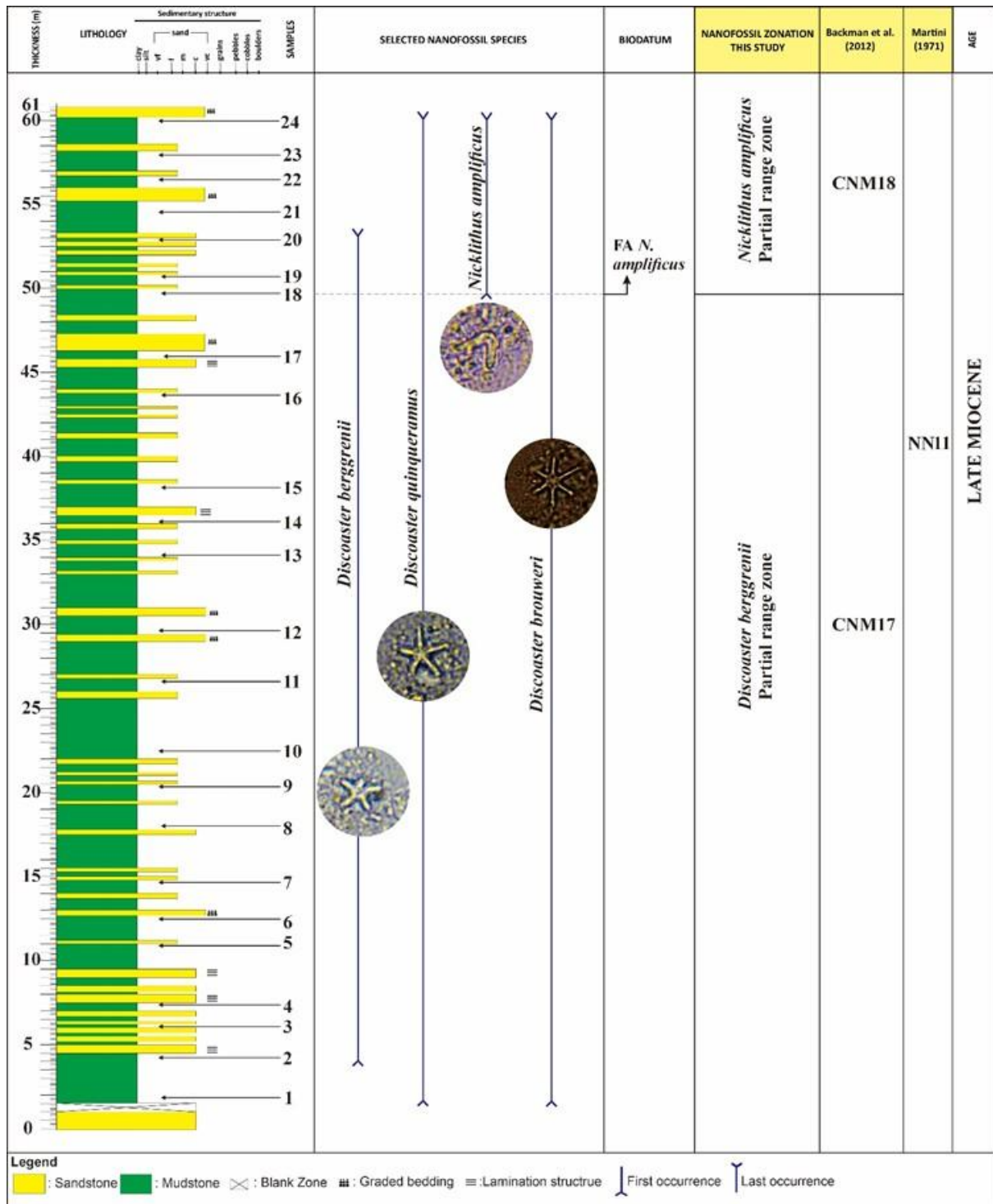


Figure 5. Stratigraphic column and biostratigraphic zones of the research area in the Bojongsana River area, Purbalingga.

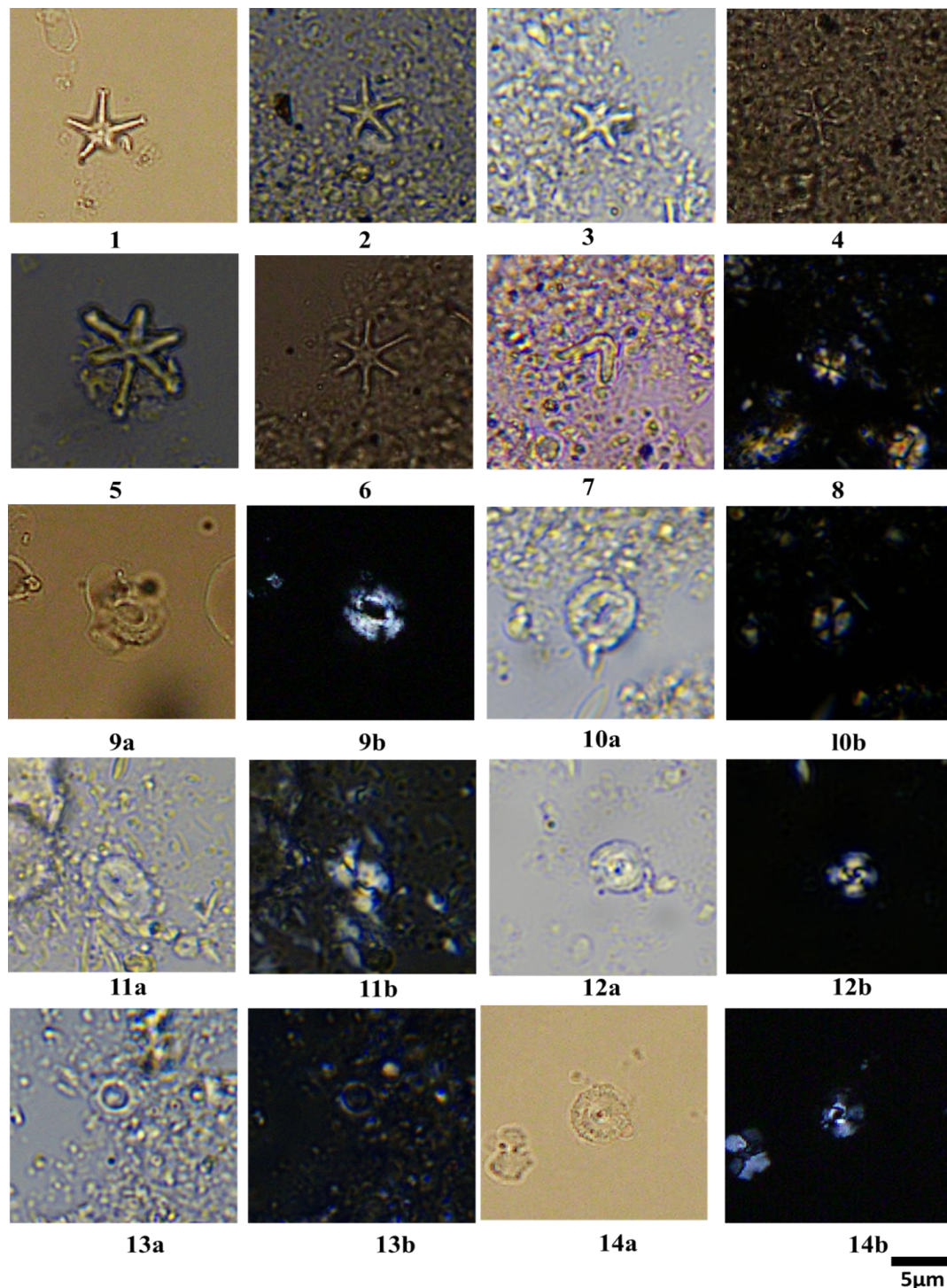


Figure 6. Selected image of a nannofossil species in this research. PPL view (a) and XPL view (b). (1) *Discoaster pentaradiatus* (sample RJW7), (2) *Discoaster quinquerramus* (sample RJW16), (3) *Discoaster bergrenii* (sample RJW2), (4) *Discoaster variabilis* (sample RJW18), (5) *Discoaster neorectus* (sample RJW18), (6) *Discoaster brouweri* (sample RJW18), (7) *Nicklithus amplificus* (sample RJW18), (8) *Sphenolithus moriformis* (sample RJW24), (9) *Reticulofenestra pseudoumbilicus* (sample RJW12), (10) *Coccolithus pelagicus* (sample RJW14), (11) *Helicosphaera carteri* (sample RJW20), (12) *Cyclicargolithus floridanus* (sample RJW3), (13) *Umbilicosphaera rotula* (sample RJW23), (14) *Calcidiscus leptoporus* (sample RJW4)

Author Contribution

Akmaluddin was responsible for conceptualization, methodology,

investigation, data curation, supervision, and contribution to the original draft, review, and editing of the manuscript. Efrilia Mahdilah Nurhidayah contributed to

methodology and investigation, performed the formal analysis, prepared the visualizations, and contributed to the original draft, review, and editing of the manuscript.

Conflict of Interest

All authors state that they have no financial or personal interests that may have affected the outcomes of this research.

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