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Short Communication: Calcareous nannofossil assemblages and age determination in Leuwi Kenit, Ciletuh Palabuhanratu Geopark, Indonesia

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Abstract. *Pratiwi SD, Nurdrajat, Pratiwy FM, Chiyonobu S. 2024. Short Communication: Calcareous nannofossil assemblages and age determination in Leuwi Kenit, Ciletuh Palabuhanratu Geopark, Indonesia. Biodiversitas 25: 3200-3207.* Our meticulous and comprehensive investigation of nannofossil diversity in Leuwi Kenit, Sukabumi District, West Java Province, Indonesia, a part of the Ciletuh Palabuhanratu UGG, where the study of nannofossils is limited, is of significant importance their implications for age determination and clarifying the geological history of the region. The initial documentation of calcareous nannofossils in the Leuwi Kenit traverse of the Cikarang Member within the Jampang Formation resulted in the identification of thirty-three species from 62 samples. The studied section reveals seven nannofossil biozones, arranged from oldest to youngest as follows: LO *Sphenolithus ciperoensis*; LO *Cyclicargolithus abisectus*; FO *Sp. disbelemnos*; FCO *Helicosphaera carteri*; FO *Sp. belemnos*; LCO *Sp. belemnos*; LO *Sp. conicus* and FCO *Sp. heteromorphus*. Notably, the abundance of *Coccolithus pelagicus*, *Cyclicargolithus floridanus*, *Reticulofenestra* spp., and *Sphenolithus* spp. characterized their occurrence throughout the section. The diversity and preservation of nannofossils were found to be good, and based on nannofossil biohorizons, the age of Leuwi Kenit spans from 24.3 million years ago to around 17.7 million years ago at Paleogene (Oligocene age) to Neogen Periode (Early Miocene age). Based on the nannofossils assemblages, results show that the area has many important indicator species, making it essential for future research on ancient ocean conditions and past climate changes within this geopark.

Keywords: Age determination, calcareous nannofossils, Geopark, Leuwi Kenit, Oligocene-Miocene epoch

INTRODUCTION

The Ciletuh Geopark in West Java Province designated Indonesia's fourth UNESCO Global Geopark in 2018, encompasses 24 geo-sites (Figure 1) influenced by the Indian Ocean; the geopark features diverse topography ranging from hilly to plain. This geopark area designation serves educational purposes, imparting knowledge in biology, geology, and culture about the uniqueness and diversity of the Earth's heritage (Ikhram et al. 2017). The oceanographic conditions in the Ciletuh Geopark also provide a paleoceanographic context worth noting regarding sea surface productivity and its correlation with global climate conditions. Variations in nannofossil assemblages can be associated with changes in productivity driven by nutrient upwelling, ocean circulation patterns, and climate fluctuations (Aguado et al. 2016). Their abundance and diversity directly reflect the level of primary productivity. Periods of high productivity are often associated with increased organic carbon accumulation, which can reduce atmospheric CO_2 and influence global climate. In this biological and geological context, calcareous nannofossils emerge as crucial components and an important part of phytoplankton stocks in nearshore and offshore waters. Calcareous nannoplankton, or nannofossils, are a heterogeneous group of marine organisms with calcareous fossil structures, generally smaller than 30 μm in size, and are significant components of the earth's biogeochemical cycles (Duchamp-Alphonse et al. 2014; Kanungo et al. 2017; Balch 2018; Dutkiewicz et al. 2020). Calcareous nannofossils are the primary producers tied to the nutrient content in surface waters; their mass accumulation rates should be an index of paleo-productivity and globally significant to the carbon cycle (Meyer and Riebesell 2015; Remy et al. 2017; Bown and Young 2019; Ballegeer et al. 2022; Maiorano et al. 2023). Their importance lies in their role in the relative dating of marine sediments, attributed to their abundance, taxonomic diversity, rapid evolution, and wide distribution in marine environments (Duchamp-Alphonse et al. 2014; Clark and Watkins 2020; Ma et al. 2020; Mancini et al. 2021; Raffi and Backman 2022; Auer et al. 2023). Calcareous nannoplankton productivity is closely related to water mass and is sensitive to nutrient levels in surrounding waters (Auer et al. 2014; Ma et al. 2023a). As a result, calcareous nanofossils have become useful tools for reconstructing paleoceanographic conditions (Marino et al. 2014; Karatsolis and Henderiks 2023). Changes in their stratigraphic assemblages in sedimentary succession reflect temporal variations in water masses at the sea surface, influenced by local and global oceanographic events. Nannofossil productivity is low in oligotrophic conditions with low nutrient supply and high in eutrophic conditions with high nutrient supply at the sea surface (Aguado et al. 2016). The nannofossil productivity represented by the nannofossil accumulation rate is an important parameter, which indicates the nutrient level of the water, and paleoproductivity variations are also useful indicators of paleoceanographic and global climate change (Marino et al. 2014; Daniels et al. 2016; Chakraborty et al. 2021; Schueth and Johnson 2023).

The example from the size of *Reticulofenestra* has been frequently utilized as a paleoenvironmental indicator in 55 myrs to recent sediments from various oceans and land sections (Sato and Chiyonobu 2009; Imai et al. 2015; Pratiwi and Sato 2016; Farida et al. 2022; Beltran et al. 2014). Calcareous nannoplankton cells are covered by calcite scales whose sizes are shown to be linearly correlated with coccolithophore cell sizes where *Reticulofenestra* sizes and assemblage compositions are directly affected by temperature, nutrients, light intensity, salinity, CO_2, and climatic changes (Jones et al. 2019; Young et al. 2021; Ma et al. 2023b). Studies on calcareous nanofossils in the Equatorial Pacific Ocean still need to be completed, especially regarding nanofossil assemblages and age history in the Ciletuh area.

Our investigation into the diversity of nannofossils, preservation conditions, and nannofossil assemblages from the Leuwi Kenit Geotourism, a part of the UNESCO Ciletuh Palabuhanratu Global Geopark, is not just about the present. Our research aims to present the calcareous nannofossil assemblage and the chronological age of the Leuwi Kenit sedimentation. By examining the nannofossil assemblages, we can reconstruct the environment at certain geological times in Leuwi Kenit, thereby supporting geological and historical data for this geopark for future research. Our findings, particularly our study of nannofossil productivity and species distribution, will be instrumental in the future research in reconstructing paleoceanography and paleoclimate history in the Ciletuh Palabuhanratu UNESCO Global Geopark.

MATERIALS AND METHODS

Study area and data collection

The study area is in the Leuwi Kenit Geosite, encompassing the Pasirpanjang village in Ciracap Sub-district, Sukabumi District, West Java Province, Indonesia. The locations chosen for collecting outcrop rock samples fall within the latitude range of 106°38'30"N to 106°39'30"N and the longitude range of 107°18'05"E to 107°19'30"E, along the Ci Karang River within the Ciletuh Palabuhanratu Geopark. This geological study of the area is encompassed by the Cikarang Member of Jampang Formation (Figure 1). The Ciletuh Palabuhanratu UNESCO Global Geopark contains several geological formations and processes that significantly impact global paleoclimates. The most important was the active subduction zone of the Indo-Australian Plate beneath the Eurasian Plate, which leads to volcanic activity and releases greenhouse gases like CO_2, influencing global climate patterns (Hall 2012). In addition, the ophiolite complex in the geopark was very important for understanding the global carbon cycle and the serpentinization process in these rocks to absorb CO_2 (Kelemen and Manning 2015). The sedimentary basins in the Ciletuh region document historical sea levels and climatic conditions, offering critical data for reconstructing past climates (Hanebuth et al. 2011). Furthermore, fossil records, including nannofossils found in these sedimentary sequences, are vital for interpreting historical climate conditions and understanding changes in global paleoclimates (Bown and Young 2019). These geological features collectively provide valuable insights into the past processes that have shaped Earth's climates and continue to influence its climate system.

Figure 1. Map study site in Ciracap Sub-district, Sukabumi District, West Java, Indonesia

The West Java field in Indonesia is subject to the influence of the South Equatorial and South Indian currents (Nurlatifah et al. 2021). Physiographically, the study area is part of the southern mountainous zone of West Java, extending from Pelabuhanratu Bay to Nusakambangan Island. Based on the regional geology of West Java, the constituent lithologies of Cikarang member that makes up the Jampang Formation comprise tuff, lapilli tuff, sandstone, mudstone, tuffaceous marl, and andesitic, basaltic, dacitic lava, and breccia (Sukamto 1975). This study marks the inaugural exploration of calcareous nannofossils assemblages and their diversity in the Ciletuh Palabuhanratu Geopark, with a specific focus on sections of rocks from 25 to 17 million years ago within the Cikarang member of the Jampang Formation (Figure 2). The rugged terrain in this region, with steep slopes and deep valleys, is shaped by active tectonic forces, with elevations reaching several hundred meters above sea level (Ummah et al. 2018). Erosional and weathering processes further contribute to its distinctive landforms. This understanding enhances the reconstruction of past environmental conditions and informs ongoing geological and paleoclimatic research (Jones et al. 2019). Rock samples with a sediment thickness of about 64 m at the Leuwi Kenit Site were prepared for microscopic observation and calculation of nannofossil productivity based on the nannofossil assemblages (Figure 3).

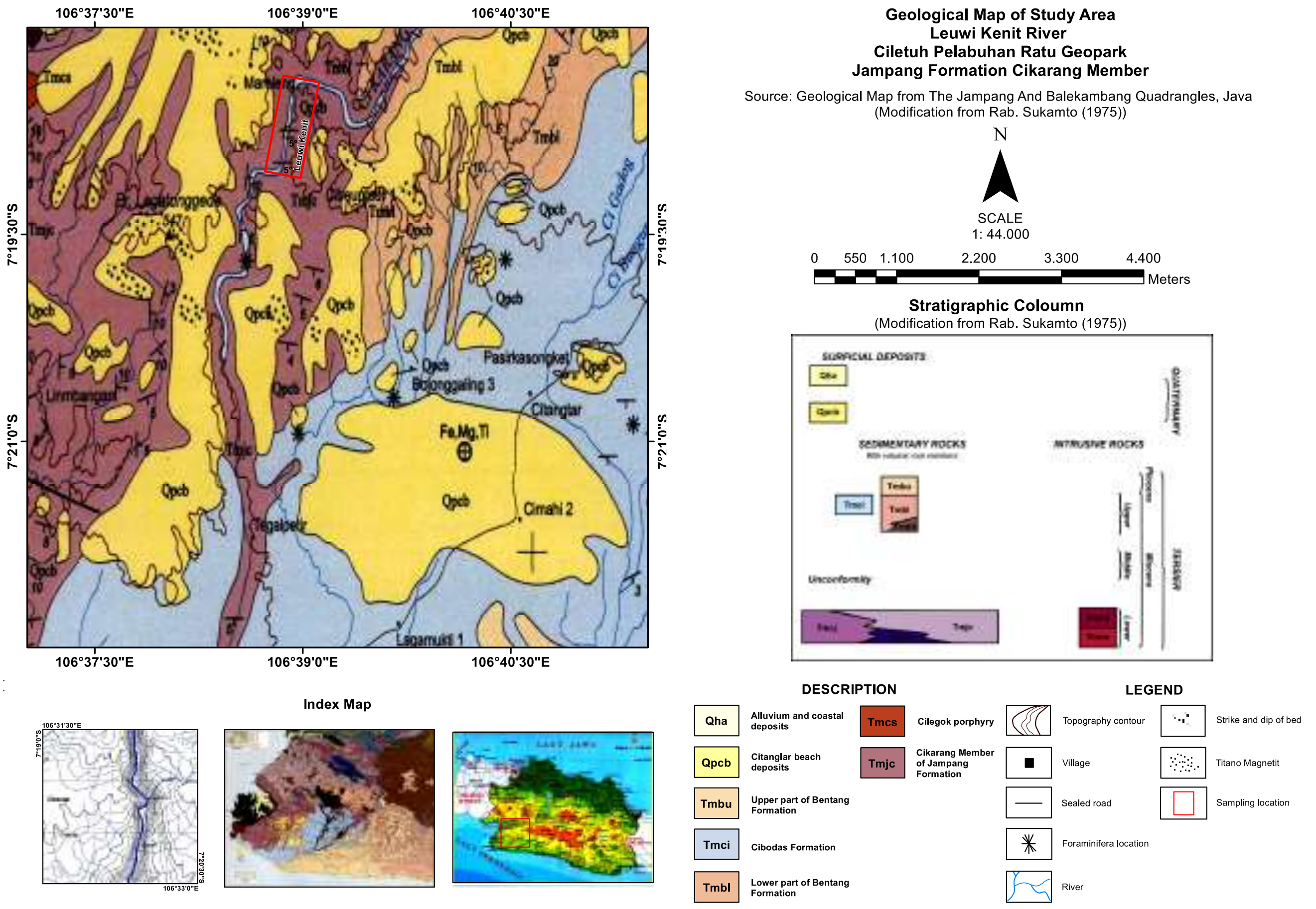

Figure 2. Geological map of the study area at Sukabumi, West Java, Indonesia (modified from Sukamto 1975)

Figure 3. The lithostratigraphic unit in the Leuwi Kenit Area, Ciletuh Palabuhanratu Geopark, Indonesia (from top to bottom sequence) comprises massive sandstone, sandstone with carbonate and non-carbonate components, and claystone

Procedure

Therefore, 62 samples were collected from rocks predominantly composed of massive sandstone, sandstone with carbonate and non-carbonate, and claystone, with a sampling distance of approximately 30 to 100 cm based on measurement stratigraphy method sampling at Leuwi Kenit. The objective was to assess the variability of nannofossil assemblages at the studied sites, and all samples were prepared for semi-quantitative methods using smear slide and observation techniques, whose results are shown below. Semi-quantitative assessments of total nannofossil and individual species abundances revealed that calcareous nannofloras are found in low to abundance quantities, with their preservation ranging from poor to good. The measured section method during field measurements resulted in an outcrop thickness of 64 meters with sampling at 30-100 cm intervals (Figure 3).

The primary preparation of samples was carried out using the rippled smear slide technique (Bown and Young 1998) and then mounted with UV-curing adhesive (Gluelabo Ltd., Kuwana, Japan). Additionally, some samples (three samples at the bottom of the sequence) were prepared as a suspension preparation method.

Nannofossils were observed to identify the last (LO) and first (FO) occurrences of age-diagnostic species, which are tied to the geomagnetic polarity timescale of Gradstein et al. (2020). Relative abundances of identified components such as mineral grains, microfossils, and biogenic fragments were assigned on a semi-quantitative basis using the following abbreviations Betzler et al. (2017), as follows: A=abundant (>10 specimens per field of view); C=common (>1-10 specimens per field of view); F=few (1 specimen per 1-10 fields of view); and R=rare (<1 specimen per 10 fields of view). The preservation of calcareous nannofossils was recorded using the following criteria: G=good; M=moderate; and P=poor.

Taxonomic concepts follow Young et al. (2003) as synthesized on the Nannotax website (http://ina.tmsoc.org/Nannotax3). The absolute age of the nannofossils in this study was established using the nannofossil age described by Sato and Chiyonobu (2013), and the Cenozoic biostratigraphic zonation of calcareous nannofossils follows Martini (1971).

RESULTS AND DISCUSSION

The primary objective of this report is to characterize the identified assemblages of calcareous nannofossils and their stratigraphic distribution. Additionally, it aims to determine biostratigraphic age using the first and last occurrences of selected species. Leuwi Kenit's research area consists of calcareous lithic rocks, with a sequence of sandstone and claystone exhibiting trace fossils and a typical molluscan fauna, including boring trace fossils. A sedimentary structure indicative of lamination and graded bedding was identified from top to bottom of the sediment rocks succession in this study area. The preservation quality of these nannofossils in the study area ranged from moderate to poor (Figure 4). Species without calcite overgrowth or dissolution exhibited moderate preservation, allowing easier identification and differentiation.

There were 33 taxa identified at species level belonging to 12 families of calcareous nannofossil and non-coccolith in Leuwi Kenit geosite area consist of Braarudosphaeraceae, Coccolithaceae, Calcidiscaceae, Calciosoleniaceae, Ceratolithaceae, Discoasteraceae, Helicosphaeraceae, Pontosphaeraceae, Prinsiaceae, Rhabdosphaeraceae, Sphenolithaceae, Syracosphaeraceae families and *Incertae sedis* (Table 1) Most samples from this interval contain nannofossils, but their abundance is common to few, and wide age range forms such as *Cyclicargolithus floridanus*, *Sphenolithus moriformis*, *Reticulofenestra* spp., and *Coccolithus pelagicus* are abundance (Table 1).

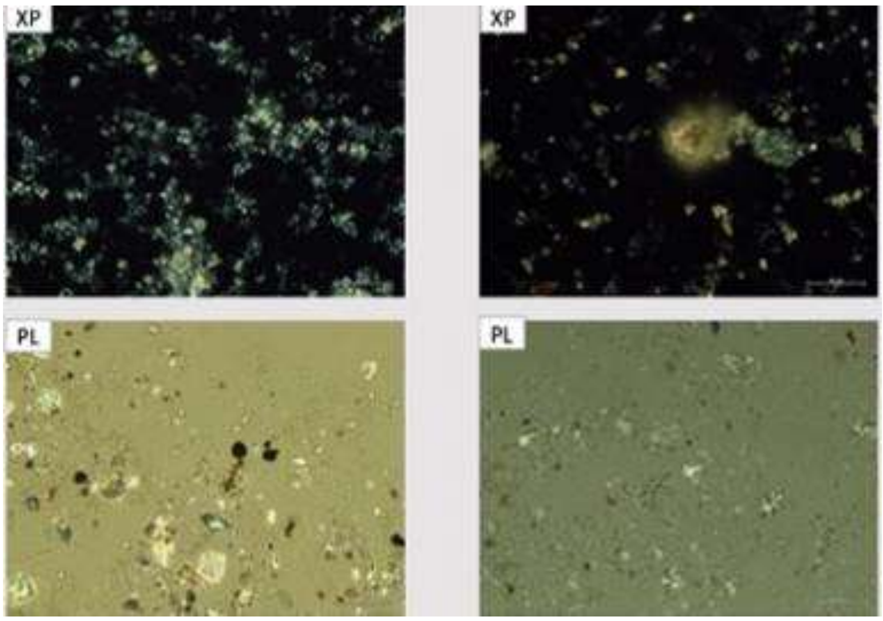

Figure 4. Photomicrographs of nannofossil preservation under the microscope (XP: Cross-polarized light; PL: Parallel light)

Table 1. Distribution of calcareous nannofossil species, assemblages, and geological age in Leuwi Kenit, Ciletuh Palabuhanratu Geopark, Indonesia. Abundance of individual calcareous nannofossil taxa is recorded as: A= Abundant (>10 specimens per field of view); C= Common (>1-10 specimens per field of view); F= Few (1 specimen per 1-10 fields of view); R= Rare (<1 specimen per 10 fields of view); P= Present (<5 specimens seen while logging slide). The preservation of nannofossil species is recorded as G= Good, M= Moderate, P= Poor. Nannofossil datum (*) and age assignments are correlated with Berggren et al. (2017)

Formation/ Location	Samples No.	Thickness (m)	Lithology	Gradstein et al. 2020: System/Period	Gradstein et al. 2020: Series/Epoch	Zonal Assignments (Martini, 1971)	Preservation	Nannofossil Zone (Sato and Chiyonobu, 2013)	Age (Sato and Chiyonobu, 2013)	*Reticulofenestra pseudoumbilicus* (>8µm)	*Reticulofenestra pseudoumbilicus* (6-8µm)	*Reticulofenestra* spp. (3-5µm)	*Reticulofenestra* spp. (<3µm)	*Cyclicargolithus floridanus*	*Cyclicargolithus abisectus*	*Calcidiscus leptoporus*	*Coccolithus pelagicus*	*Coccolithus* sp.	*Sphenolithus conicus*	*Calcidiscus macintyrei*	*Umbilicosphaera* sp.	*Umbilicosphaera rotula*	*Umbilicosphaera jafari*	*Hayaster perplexus*	*Helicosphaera* spp.	*Hughesius tasmaniae*	*Hughesius gizoensis*	*Helicosphaera carteri*	*Helicosphaera euphratis*	*Helicosphaera obliqua*	*Pontosphaera* sp.	*Sphenolithus heteromorphus*	*Scyphosphaera apsteinii*	*Rhabdosphaera clavigera*	*Braarudosphaera bigelowii*	*Discoaster* spp.	*Sphenolithus ciperoensis*	*Reticulofenestra bisecta*	*Sphenolithus belemnos*	*Sphenolithus moriformis*	*Sphenolithus disbelemnos*	*Triquetrorhabdulus carinatus*	*Triquetrorhabdulus milowii*	*Calciosolenia* sp.	*Thoracosphaera heimii*	*Thoracosphaera* sp.	*Ilselithia fusa*	*Sphenolithus* spp.	*Coronocyclus nitescens*
Cikarang Member of Jampang Formation / Leuwi Kenit Traverse, Sukabumi -West Java	LP 1	0,53	Sandstone	NEOGENE	Miocene	NN4	M			R	R	C	C	C		P	C		C			C		R			F			R	R							P									
	LP 2	0,61	Sandstone				M			C	C	A	A	A		R			F					R							R							C									
	LP 3	0,74	Sandstone				M			F	R	R	A	A		R			P	C				P							P							C									
	LP 4	0,8	Sandstone				M			C	C	C	A	C		F	R	P	C	F		R					R	R		F	R	R		P			F								P	
	LP 5	1,1	Sandstone				G			R	R	C	A	A		R	R	R	F	P		R				P	R			F				P			A								P	
	LP 6	1,85	Sandstone				G	FCO *Sphenolithus heteromorphus*	17.721 Ma	R	R	R	A	R		R	R		C	C						P	R			R							F								P	
	LP 7	1,91	Claystone				M				R	R	C	F		R	P		A	F						P	R										A								P	
	LP 8	2,01	Claystone				M			R	R	R	C	A		R			C	C		R					R					P					F								P	
	LP 9	2,13	Sandstone				M	LO *Sphenolithus conicus* (*)	17.95 Ma (*)		R	R	R	A		R	P	P	R	A		R				P	P										PR								P	
	LP 10	2,43	Sandstone	NEOGENE		NN3	M	LCO *Sphenolithus belemnos*	17. 973 Ma		F	C	C	A		R	C		F	C		F					F						P				CA		P						P	
	LP 11	2,63	Sandstone				P				R	F	F	A		R	R		R			R					R										AA									
	LP 12	2,71	Sandstone				M					P	P	P		R	P		R			P	P		R	R	P	PP	P								FC					P			P	
	LP 13	2,86	Sandstone				M			C		R	C	A		R	R		R		R	R	P			R											PA								P	
	LP 14	3,69	Sandstone				G			A		F	C	A		R	F		R		R	C	P				R	RP	P								AR								P	
	LP 15	3,8	Sandstone				G	FO *Sphenolithus belemnos*	18.921 Ma	A		A	C	A		P	F		R	F		C					R										FA						P		P	
	LP 16	4,3	Sandstone			NN2	M					A	C	A			C		R			F	P				R	R										R						P		R	
	LP 17	4,38	Claystone				P				P	P	P	P		P	R		C		R	F	P					R										A								R	
	LP 18	4,55	Claystone				P				P	P	P	P					R								F	R	P	P										F								F	
	LP 19	5,16	Sandstone				M				R	R	R	C			C		R				R						R										A								F	
	LP 20	5,36	Sandstone				G					A	A	A		P	C		R	P		C					F	P	P								C					P			P	
	LP 21	6,23	Sandstone				M					R	R	C					R							R														F	P								P	
	LP 22	6,38	Sandstone				P				P	R	R	C		P	P		R						P				P										F	P								F	
	LP 23	6,58	Sandstone				M					R	R	A			F		R				C				P	F											P	F								R	
	LP 24	6,83	Sandstone				P				R	R	R						R							R															P	R								
	LP 25	7,01	Sandstone				P				F	R	R				F		R						P															F	P								
	LP 26	7,15	Sandstone				M				C	R	R				R		F	P	C				R	R	R								P					R	R								
	LP 27	7,25	Sandstone				M			C	C	C	F	F			R		R				F			R		R													R							P	
	LP 28	7,33	Sandstone				P			R	C	C	R	R			R		P				C			P	P	P	P											P	P		P						
	LP 29	7,56	Sandstone				M	FCO *Helicosphaera carteri*	21.985 Ma	R	C	R	R	C			F		P				C			F		R	P						P					P					P			
	LP 30	7,82	Sandstone				M				F	C	R	R			F		P	P		R				P	P		P	P						P			F	P	P	P			P			
	LP 31	7,91	Sandstone				P			P	F	R	R	F			F		P	R						R													P	P	F							
	LP 32	7,99	Sandstone				G			P	R	F	R	R			F		P	R				P		R		R	P	P										F	P						P	
	LP 33	8,36	Sandstone				G			P	F	R	R				F		P	P	P						R		R											C	P						P	
	LP 34	8,44	Sandstone				G			P	C	R	R				F		P	P						C		R	P										R	P						P	
	LP 35	8,58	Claystone				G	FO *Sphenolithus disbelemnos*	22.413 Ma		R	R	R						P	P																			R							P	
	LP 36	8,66	Claystone	PALEOGENE	Oligocene	NN1	M				R	R	R	R					P	R									P																	P	
	LP 37	8,81	Sandstone				M				C	R	R						F	R				P																					P	
	LP 38	8,91	Sandstone				G				R	F	R	C					P	R															P												P	
	LP 39	8,96	Sandstone				M				F	R	R	C					P	P				P																						P	
	LP 40	9,54	Sandstone				M				C	R	R	R					P	F				P										P												P	
	LP 41	10,98	Sandstone				M			R	C	R	R	C			P					C						C						P				P								F	
	LP 42	11,81	Sandstone				M			C	A	C	R	C			P					F			P			PP	P								R				P	P			C	P
	LP 43	12,81	Sandstone				M					C	R	C			P			P		F	P				P				P		P	P			P								R	
	LP 44	13,06	Sandstone				P				F	P	P	C			P								P				R	R		P															P	
	LP 45	14,41	Sandstone				P				P	P	P	P			P						R				P		R										P						P		P	
	LP 46	15,81	Sandstone				P				P	P	P	R			P						P					R	P								P		P				P		P	P	P	P
	LP 47	17,22	Sandstone				M				F	C	C	C			P			P								R						P				R							F	F	
	LP 48	18,98	Sandstone				G				R	F	F	A				C				R		P				RP			P						R			P				F	F	
	LP 49	20,79	Sandstone				M					C	F	F				R				C										P					P	R							F	F	
	LP 50	22,72	Sandstone				G	LO *Cyclicargolithus abisectus*	22.8 Ma			R	C	A	C			P						P				R						P				R		P	P		P			P	
	LP 51	24,82	Sandstone				P				P	F	P	P	R		P	C		P				R				R										R									
	LP 52	25,37	Sandstone				M					A	C	C	C																									R									
	LP 53	28	Sandstone				M					A	C	A	C		P	P		P		F		P															R							P	R	
	LP 54	30,79	Sandstone				M				R	R	C	R	C			C				C		P															R				P					P
	LP 55	33,65	Sandstone			NP25	M	LO *Sphenolithus ciperoensis*	24.389 Ma			F	F	C	C			F				C		P											F	P		F									
	LP 56	36,8	Sandstone				M				R	R	R	C	C			P				R		R									P	F			R							P		
	LP 57	40,3	Claystone				P				P	P	P		A										R												R			F								R	
	LP 58	43,82	Claystone				P				P	R	P		P										P												P			R									
	LP 59	49,8	Claystone				M				R	R	C		A					P				P												P			R								R	
	LP 60	53,4	Claystone				M					C	P		C									R					P							P			R									
	LP 61	57,63	Claystone				P						P		P																																	P	
	LP 62	63,5	Claystone				P					P								P									P																		P	

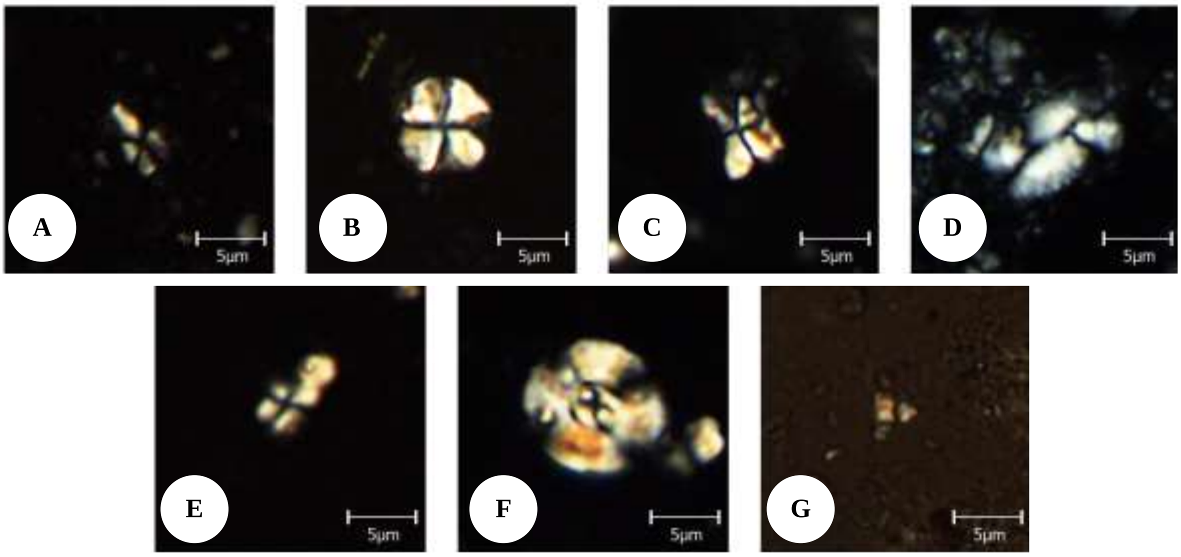

Figure 5. Photos of index calcareous nannofossils species or nannobiozones for the studied section in cross-polarized from Cikarang Member of Jampang Formation. A. *Sphenolithus heteromorphus*; B. *Sp. conicus*; C. *Sp. belemnos*; D. *Helicosphaera carteri*; E. *Sp. disbelemnos*; F. *Cyclicargolithus abisectus*; G. *Sp. ciperoensis*

The abundance and assemblage of the species distribution decreases and repeats abruptly at the base of the section. Discoasters were very rare and difficult to identify at the species level. Based on the stratigraphic distribution of key species, we correlated the sequence with Martini's (1971) Nannofossil zone. The age of young bioevents in this interval is well constrained by a series of Early Miocene datums, and the basal age by the First Common Occurrence (FCO) *Sp. heteromorphus* nanofossil datum in a sediment thickness of 1.85 m (17,721 Ma). Specifically, the interval at the Leuwi Kenit Site correlates to the Nannofossil Paleogene (NP 25) at 24.389 Ma until 17,721 Ma (absolute age is referring to Sato and Chiyonobu 2013), extending to the nannofossil. On the Oligocene Zone, *Reticulofenestra pseudoumbilicus* and small-size of *Reticulofenestra* spp. are consistently present throughout the Miocene interval from 63.5 m to 0.53 m, with the highest relative abundance of *Reticulofenestra* spp. (<3 microns) recorded between 1.85 m and 0.61 m. The First Occurrence (FO) and last occurrence (LO) of *Sp. delphix* were absent in the NN1 Zone. The last occurrence of *Cy. abisectus* is clearly observed at a thickness of 22.72 m. Although nannofossils were present in most samples from this interval, they were typically at very low abundances, with only long-ranging forms such as *Braarudosphaera bigelowii, Coronocyclus nitescens, Helicosphaera euphratis, Umbilicosphaera rotula, Hayaster perplexus,* and *Pontosphaera* sp. being observed. Abundances and diversity slightly increased down-section, with *Sp. ciperoensis* indicating its last occurrence at 33.65 m. The sequence of this site is correlated to the top of the Oligocene to early Miocene epoch from sample LP 35 to sample LP 1 (Table 1).

Nannofossils in the NN2 Zone were generally rare and moderately well-preserved, allowing for the placement of reliable marker events. Notable markers include the First Occurrence (FO) of *Sp. disbelemnos*, and the First Common Occurrence (FCO) of *He. carteri*. The *He. obliqua, Pontosphaera* sp., *Triquetrorhabdulus milowii* and *Tr. carinatus* was present - poorly preserved in this zone and absent in the NN4 Zone.

The interval between Sample LP 15 (3.8 m) and LP 10 (2.43 m) is assigned to the early Miocene at Zone NN3. In this section, nannofossils are well-preserved and moderately overgrown, with *Cy. floridanus*, *Calcidiscus leptoporus*, *H. carteri*, and *Sp. moriformis* dominating the flora. The upper part of the early Miocene sequence shows moderate preservation with slight to moderate overgrowth, especially on *Reticulofenestra* spp. Other species observed include *Co. pelagicus*, *Ca. macintyrei*, *U. jafari*, *Sp. heteromorphus, Scyphosphaera apsteinii*, *Sp. moriformis, Discoaster* spp., and *Ca. leptoporus*. *Cy. floridanus*, which covers about 80% of the Oligocene-Miocene epoch, dominates the lower to upper part of early Miocene Zone and is a typical event in the Miocene assemblage, proving to be a useful tool for correlation. The upper part of the sequence is marked by the abundant presence of *Sp. conicus*, constituting 20% to 50% of the assemblages, while *Reticulofenestra* spp., dominate the middle to upper sections, contributing 30% to 70% of the assemblages. *Sp. conicus* is also identified as a biozone nannofossil due to this species consistently appears from LP 40 (9.54 m) to LP 9 (2.13 m). The last occurrence of this species is recorded at the boundary between the NN3 and NN4 Zones, dated to 17.95 Ma (referring to Bergen et al. 2017).

Notably, *Reticulofenestra* spp. (<3µm) decrease to absent in the lower part of the NN1 Zone, while *Sp. conicus* peaks from the top to the base of this zone; *Cyclicargolithus*, a reticulofenestrid coccolith, is this study site's most common species. At the same time, a rare nannofossil in this zone is *Umbilicosphaera*, typically an oligotrophic taxon, which contrasts with Discoasters, which indicates warm water conditions but is not found in all samples. The presence of warm-water taxa such as *Sphenolithus* and a decrease in cold-water species like *Co. pelagicus* between 24.389 million years ago and 17.721 million years ago suggests climatic warming at the Oligocene-Miocene boundary under oligotrophic conditions (Kanungo et al. 2017). The most noteworthy feature was the continued abundance of *Reticulofenestra*, *Sphenolithus* and *Cyclicargolithus*, providing a foundation for future research in interpreting paleoceanography and reconstructing paleoclimatology (Bergen et al. 2017; Galović 2017; Kasem et al. 2022). In conclusion, at least 33 taxa have been identified to the species level of calcareous nannofossils were identified from Leuwi Kenit traverse of Cikarang member of Jampang formation at Sukabumi, West Java, covering the age period from 24.3 to 17.7 million years ago (NP 25 to NN4 Zones). It is important to update the geologic age of this formation from the age indicated in the regional geology.

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