Calcareous nannoplankton of Paleogene sediment from the Bayat area, Central Java-Indonesia

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Abstract

Calcareous nannofossils of the Wungkal Formation in the Bayat area were studied in order to obtain new age-diagnostic data. Previously, the Paleogene sediments in the formation have been determined as Eocene based on the assemblage of larger foraminifera. The nannofossils observed in the Wungkal Formation range from the late Eocene (CP 14) to early Oligocene (CP 16c). The Eocene/Oligocene boundary is recognized by the last occurrence of *Discoaster saipanensis*, *Discoaster barbadiensis* and *Cribrocentrum reticulatum*. The Subzone CP 16c in the upper part of the section was identified by the co-occurrence of *Reticulofenestra umbilicus*, *Cyclicargolithus floridanus* and *Reticulofenestra bisecta*.

Key words : Eocene/Oligocene boundary, calcareous nannoplankton, marker species, facies change

Introduction

In the Bayat area Pre-Tertiary metamorphic and igneous rocks are unconformably overlain by the Lower Tertiary sedimentary rocks of mostly marine environment (Marks, 1957).

The Paleogene sediment in Bayat is distributed over wide area and encompassed entirely by Pre-Tertiary rocks as in the other Paleogene sediment occurring in the Java Island.

The lithology of Paleogene sediment in the Bayat area is more diversified than that of the other areas such as, Nanggulan and Karangsambung. The different facies of the Bayat Paleogene sequence are also identified by the dominant faunal content. Previously, the study of biofacies is based on abundant microfossils occurring as large benthic and planktonic foraminifera. Based on the occurrence of large benthic foraminifera *Discocyclina javana*, *Discocyclina dispansa* and some planktonic foraminifera such as *Truncorotaloides rohri*, *Globorotalia pamei* and *Globigerina spinulosa*, Marks (1957) identified the Eocene age for the sequence.

The Paleogene sedimentary sequence of Bayat area is separated into two distinct formations, the Wungkal and Gamping Formations (Bothe, 1929). The Wungkal Formation consists of conglomerates and quartz sandstones intercalated by shales and irregular limestones, whereas the Gamping Formation consists mostly of limestones intercalated by marls. This limestone unit contains many large *Nummulites* and

Discocyclina.

Calcareous nannofossils have never been reported for the Bayat Paleogene sediment, and therefore the main purpose of this study is to examine the nannofossil biostratigraphy for this sequence.

Geologic setting

Geologically, the sedimentary sequence covering in this area belongs to the Southern Mountains, and it can be subdivided into two different basins, the Baturagung and Pacitan basins. The Baturagung basin, where Bayat locates is in the southeast of Yogyakarta, Central Java, whereas the Pacitan basin situates in the eastern part of the Baturagung basin. The interested Baturagung basin is shown in Fig. 1. The Baturagung Basin covered succession of the Tertiary sediment, ranging from the Eocene to Pliocene age.

The oldest exposed rock in the Baturagung basin is a resistant Mesozoic metamorphic body consisting of schists, phyllites, and igneous rocks forming two prominent isolated hills. The Paleogene formations distribute in limited areas, mainly around and on top of the metamorphic rocks. In the eastern part of Bayat area, the Pre-Tertiary and Lower Tertiary rocks are intruded by diorite, porphyrite and basalts (van Bemmelen, 1948 ; Kadar et al., 1977).

Several outcrops of the Paleogene units are observed especially rock unit distribution at the Gunung Pendul area near Giriharjo village. The Wungkal Formation consists mainly of sandstone and gray

Fig. 1. Location of the studied area and geologic map of the Bayat area, Central Java.

AGE		BATURAGUNG BASIN	STUDIED AREA
Quaternary		Alluvium/Volcanic	Alluvium/eluvium
Pliocene		Wonosari Fm
Miocene	Late	Oyo Fm
	Middle	Sambipitu Fm	
	Early	Nglanggran Fm	
Oligocene		Semilir Fm
Eocene		Kebo-Butak Fm	
Pre Tertiary		Wungkal Fm
		Gamping Fm	
		Melange	Schist, Phyllite

Fig. 2. Stratigraphic succession of the Baturagung basin and studied area.

mudstone, whereas the Gamping Formation is composed mainly of limestone containing large foraminifera such as *Nummulites* and *Discocyclina*.

The good exposures of the Gamping Formation located at Watuperahu near Penggingan village, consists of limestone containing larger foraminifera abundantly. A great numbers of loose specimens of *Discocyclina javana*, *Discocyclina dispansa*, *Assilina granulosa*, *Nummulites javana*, and *Nummulites bagelensis* are easily collected. Shale and coarse sandstone, which overlie the limestone, contain scarce planktonic foraminifera, such as *Globorotalia aspensis*, *Acarinina (Globorotalia) bulbrooki*, *Globigerina boweri* and *Globigerina yeguaensis* indicating the middle Eocene (Kadar et al., 1977).

The simplified stratigraphic of the Baturagung basin and studied area are shown in Figure 2.

Material and procedure

The stratigraphic column sectioning was conducted at the eastern side of Gunung Pendul in the vicinity of Giriharjo village, locating 20 km east of Yogyakarta. Relatively fresh and undisturbed samples were taken from the Wungkal Formation exposed in the area of Bayat, and thirty two samples were examined microscopically to identify calcareous nannofossils. The thickness of this section is more than 70 meters, composing mainly of finegrained sandstones and mudstones. Samples were prepared for observation under a polarizing light microscope at 1,000-1,500 X

magnification. Smear slides were prepared by spreading a suspension of sediment in water, on to a coverglass, and "Entellan" was used to attach the coverglass to the microscope slides. A total of 20 species were identified through this study. The standard zonation of Okada and Bukry (1980) was employed for the analysis of biostratigraphy.

Nannofossil biostratigraphy

The Cenozoic nannofossil zonation of Martini (1971) was sometimes difficult to apply in the Central Java regions due to the lack of some subtropical marker species. We utilize coccolith biostratigraphy of Okada and Bukry's (1980) and supplement of Bukry's (1973, 1975) for this regions that is suitable for the low latitude coccolith biostratigraphy. In the 32 samples studied in this report calcareous nannofossils occur only rarely or in few categories (Table 1).

Generally, nannofossils are scarce in the lower part of the exposed section of the Wungkal Formation in the vicinity of Giriharjo village. Preservation of nannofossils is generally poor due to advanced recrystallization except in two samples that contain relatively rich nannofossil assemblages. The dominant species are *Cyclicargolithus floridanus* and *Reticulofenestra bisecta*.

In the section I (Fig. 3.), the lowest part of the Wungkal Formation contains limited and poorly preserved assemblage, and samples BT 8 through to BT 17 are barren of nannofossils. In the section II, the

Table 1. Occurrence of calcareous nannofossils in the outcrop samples from the Giriharjo section, Gunung Pendul, Bayat area.

Sample number (BT)	06	07	18	19	19a	20	21	22	23	25	26	29	30
Abundance	F	R	F	F	F	C	C	C	R	C	C	R	C
Preservation	P	P	P	P	P	P	P	P	P	P	P	P	P
<i>Criboecentrum reticulatum</i>	+	-	+	+	+	+	+	-	-	-	-	-	-
<i>Coccolithus eopelagicus</i>	-	+	-	+	-	-	+	+	-	-	-	-	+
<i>Coccolithus pelagicus</i>	-	-	+	+	+	+	+	-	+	+	+	-	+
<i>Coronocyclus protoannula</i>	-	+	+	+	-	+	+	-	-	-	-	-	+
<i>Cyclicargolithus floridanus</i>	-	-	+	+	+	+	+	+	+	+	+	-	+
<i>Cyclicargolithus luminis</i>	-	-	-	+	-	+	+	-	-	+	+	-	-
<i>Reticulofenestra bisecta</i>	-	-	+	+	-	+	-	+	-	-	-	-	-
<i>Reticulofenestra scrippsae</i>	+	-	+	+	-	+	+	-	-	-	-	-	-
<i>Discoaster deflandrei</i>	-	-	-	+	-	-	+	-	-	-	-	-	-
<i>Discoaster barbadiensis</i>	+	+	-	+	+	-	+	-	-	-	-	-	-
<i>Discoaster saipanensis</i>	-	-	-	+	+	-	+	-	-	-	-	-	-
<i>Discoaster tani nodifer</i>	-	-	-	+	-	-	+	-	-	-	-	-	-
<i>Discoaster elegans</i>	-	-	-	-	-	-	+	-	-	-	-	-	-
<i>Ericsonia formosus</i>	-	-	-	+	-	-	+	-	+	-	-	-	-
<i>Helicosphaera seabrai</i>	-	-	-	-	-	+	-	-	-	-	-	-	-
<i>Reticulofenestra umbilicus</i>	+	+	+	+	-	+	+	-	-	+	-	-	+
<i>Sphenolithus moriformis</i>	+	-	-	+	+	+	+	+	-	+	+	-	-
<i>Ericsonia fenestrata</i>	-	-	-	+	-	+	-	-	-	+	+	-	-
<i>Reticulofenestra</i> sp.	-	-	-	+	-	+	+	-	-	-	-	-	-
<i>Coccolithus</i> sp. (small)	-	-	-	-	-	+	+	-	-	+	-	-	-
Nannofossils zonation	CP 14 – CP 15					/		CP 16					

C = common; F = frequent

R = rare

M = moderate; P = poor

+ = present

- = absent

nannofossils are fairly well preserved in samples BT 19 to BT 21. The samples BT 6, BT 7, BT 19, BT 20, and BT 21 are the lowest part of the Wungkal Formation. *Discoaster saipanensis*, *Discoaster barbadiensis*, *Reticulofenestra bisecta*, and *Criboecentrum reticulatum* are dominant and occur persistently throughout the samples.

The minor constituents throughout the lower part of the Wungkal Formation are *Helicosphaera seabrai*, *Ericsonia fenestrata*, *Discoaster deflandrei*, *Discoaster tani nodifer*, *Discoaster elegans*, *Coronocyclus protoannula*, *Coccolithus pelagicus*, *Coccolithus eopelagicus* and *Cyclicargolithus luminis*. *Reticulofenestra umbilicus* and *Sphenolithus moriformis* occur in fair abundance and common to all

samples. Because of the presence of *Reticulofenestra bisecta*, the flora is not older than CP 14.

Samples BT 19, BT 20, and BT 21 contain moderately diversified and poorly preserved assemblages. The sample BT 21 from the middle part of Wungkal Formation includes the index species *Discoaster saipanensis*, *Discoaster barbadiensis*, and *Criboecentrum reticulatum*, and the last species is absent above this sample. The sample BT 21, therefore, may be defined to be Subzone CP 15b. Because *Chiasmolithus grandis* and / or *Chiasmolithus oamaruensis* are missing, Zones CP 14 and CP 15 is difficult to separate in this area.

In the datum event of Paleogene, Martini (1971) and also Okada and Bukry (1980) used the two species as

Fig. 3. Columnar section of the Wungkal Formation in the Giriharjo area.

Fig. 4. Stratigraphic distribution of selected calcareous nannoplankton species in the Wungkal Formation.

the key species to define the boundary between Zones NP 16/NP 17 or CP 14/CP 15. By the occurrence of *Cribrocentrum reticulatum* and *Reticulofenestra bisecta* together, Okada (1992) indicated the late Middle to Late Eocene for the Oniike Formation of Kyushu Island, Japan. The similar association is found in the lower part of the Wungkal Formation. Therefore, based on the assemblage of nanoflora from the samples BT 19 to BT 21, the age of the lower part of the Wungkal Formation has been defined tentatively to be the Late Eocene, Zones CP 14 b-CP 15 b.

Discoaster saipanensis and *Discoaster barbadensis* whose LO define the boundary of Zones CP 15/CP 16 of Okada and Bukry's (1980) or Zones NP 20/NP 21 of Martini's (1971), are still identified in the Sample BT 21. Since they are absent above this sample, sample BT 21 is supposed to be the boundary between Zones CP 15/CP 16 (Fig. 4). The disappearance of *Cribrocentrum reticulatum* above this sample also confirms this conclusion. (Bukry, 1975; Perch-Nielsen, 1985; Backman, 1986; Monechi, 1986).

Sample BT 22 to Sample BT 30 contains scarce nanofossils, *Cyclocargolithus floridanus* and *Reticulofenestra bisecta* remain dominant to the upper part of the section. Zones CP 16 a-CP 16 b is marked by the last occurrence of *Ericsonia formosa* at the top boundary. Subzone CP 16 a and CP 16 b is hard to be

distinguished because the absent of *Ericsonia subdistischa* as specific taxa for the boundary of Zones CP 16 a and CP 16 b.

As *Reticulofenestra umbilicus* is still recognized in Sample BT 30, the upper part of this section belongs to Subzone CP 16 c. Other species are difficult to recognize due to their small size and the poor preservation. These species belong to genera *Reticulofenestra* and *Coccolithus*.

Discussion

Available stratigraphic data provided some information for the Paleogene geohistory in Bayat area. Previously, the age determination of Paleogene sediment is based on the large benthic and planktonic foraminifera. According to Bothe (1929), two distinctive formations has been distinguished. The first is the Gamping Formation which typically consists of limestones and marls with foraminifera representing a shallow marine environment. This formation contains many large forams indicating the late Eocene age (Tb). Key criteria for this judgement are occurrence of *Pellatispira mandarazi* and absence of *Assilina*. Secondly, the Wungkal Formation consisting of quartz sandstones, limestones and shales, contains some benthic foraminifera such as *Assilina spira*, *Assilina granulosa*, *Nummulites javana*, *Nummulites*

bagelensis and *Discocyclina sowerbyi*. This fauna indicates early Eocene in age.

The mudstone layers occurring in the lower part of the Wungkal Formation are intercalated by sandstones and tuffaceous sandstones reflecting an upward change to an open marine depositional environment. According to Bothe (1929) and Kadar et al. (1977), the Wungkal Formation is older than the Gamping Formation. However, the result of recent study confirms the closeness of age for these formations. By the nannofossil assemblages, the Wungkal Formation is defined to Zones CP 14-CP 16 or middle Eocene to early Oligocene, so the Wungkal and Gamping Formations had developed almost at the same stage.

We believe that the age difference between the two mentioned formations is not significant, and their sedimentary facies are discussed in the following. Nannofossils are good age indicators for pure marine environments. Due to their extremely small size, however, coccoliths are easily removed from their deposited place in a high energy environment. Several genera are more common in marginal sea than in open seas, and according to Saito and Okada (1984), several species can be used to recognize paleodepth. According to Shafik (1978), more abundant and higher diversity of the autochthonous species should be reflected shallow and nearshore environment or warm (*Discoaster* spp.) and cold surface water (*Chiasmolithus* spp.). The presence of *Cribrocentrum reticulatum* and *Discoaster saipanensis* in the lower part of the Wungkal Formation, is taken to indicate that the formation was deposited in an open marine or deeper water condition (Shafik, 1983). It is supported by the lithologic evidence consisting thick bedded claystones intercalated by thin sandstone layers. Above the Eocene/Oligocene boundary, nannofossil content is less diversified and common bioturbation persists in the sandstones indicating a shallow depositional environment.

The numerous occurrence of nannofossils in several levels suggests an open-marine condition during the late Eocene through early Oligocene. The open marine environment where the lower part of the Wungkal Formation was deposited during the middle-late Eocene had change to a shallow marine environment in the Eocene/Oligocene boundary time in the Bayat area.

Nannofossils of the Paleogene sediments in Central Java such as Bayat, Nanggulan and Karangsambung areas show extremely different faunal associations. Many nannofossils occur in the Nanggulan and Karangsambung areas that in the Bayat area where nannofossils are mostly rare. A typical open marine environment expressing olistostromal condition in the Karangsambung area reflects a mixed nannofossil assemblage of the Cretaceous and Paleogene associa-

tion and in some parts show that the *Reticulofenestra umbilicus* is significant (Hadiwisastra and Kumai, 2000).

In the Nanggulan area, a facies change from the carbonate-poor lower to the carbonate-rich upper parts of Nanggulan Formation indicates a shift from lagoonal or near shore condition to an open marine setting (Gerth and Oppenoorth, 1929 ; Hartono, 1969). The depositional change mentioned above is supported by the stratigraphic change of nannofossil assemblage.

Braarudosphaeraceae such as *Pemma* and *Micrantholithus* are dominant in the lower part of Nanggulan Formation, and *Chiasmolithus* sp. occurs in the middle part of this formation. In the upper unit, *Cyclicargolithus* sp. is found as dominant taxa. This stratigraphic change in the floral assemblage indicates a progressive deepening for the Nanggulan area. Thus it is likely that a tectonics has influenced to the sedimentary basin development at this area during the Paleogene times.

Conclusion

Although the Paleogene sediments in the Bayat area are scarce and spread over a wide area with limited exposures, the stratigraphic section near Gunung Pendul provided good biostratigraphic records across the Eocene/Oligocene boundary.

The calcareous nannoplankton biostratigraphy proved that the age of Wungkal Formation ranges from the late Late Eocene to early Early Oligocene, correlative to Zones CP 14/CP 15 to Zones CP 16c. The extinction of *Discoaster saipanensis* and *Discoaster barbadiensis* are still valid to define the boundary between Zone CP 15 and Zone CP 16 or the Eocene/Oligocene boundary.

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Hadiwisatra, S. and Kumai, H., 2000, Calcareous nannoplankton of Paleogene sediment from the Bayat area, Central Java-Indonesia. *Jour. Geol. Soc. Japan*, **106, 651-658.** (サブリ, H.・熊井久雄, 2000, インドネシア, ジャワ島バヤット地域の古第三系から産出した石灰質ナンノプランクトン. 地質雑, **106**, 651-658.)

ジャワ島のバヤット地域の古第三系は, その岩相層序学的特徴からから, 下位より主として石灰岩からなるガンピン累層と, 礫岩, アルコーズ砂岩とそれらに挟在する頁岩からなるウンガル累層に区分される. 従来, これらの堆積物は, 大型有孔虫と浮遊性有孔虫などの組み合わせに基づいて始新統に対比されてきた.

筆者等はこのバヤット地域の堆積物について, 石灰質ナンノ化石の群集組成を明らかにしたうえで, 従来の年代層序を再検討した. その結果, 2箇所のセクションから20タクサの石灰質ナンノ化石を確認し, その組み合わせから, この地域のウンガル累層の堆積年代を後期始新世から前期漸新世のCP 14からCP 16cに対比した. ウンガル累層下部と上部の境界では *Discoaster saipanensis* と *Discoaster barbadiensis* の消滅が認められ, この境界が漸進世/始新世境界を指示することが判明した.