Calcareous Nannofossil Assemblages of Tonasa Formation Palakka Area, South Sulawesi: Implication of Paleoenvironmental application

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Abstract. Tonasa limestone formation in this area consists of interbedded between marl and limestone, which were developed intensively in the marine environment from the Late Eocene to Oligocene. One important component of this rock is Calcareous nannofossil as the primary production of CaCO3. The aim of this study are to obtain data from the distribution of calcareous nannofossil, assemblages and early investigation about the implications for the paleoenvironment. Calcareous nannofossil is a good indicator for determining paleoenvironmental conditions such as modern coccolithophores that show seawater stratification. The material under study came from the outcrops of the Barru River, which were collected by measuring section method, then the samples were prepared using the smearslide technique. The result are the presence some marker species such as Sphenolithus distentus, Distylococcites bisectus, Zygrhablithus bijugatus, Phontosphaera enormis, Cyclicargolithus abisectus, Sphenolithus pseudoradians. The presence of Discoaster as typical warm water organism characterize the deep photic zone, therefore indicates stratified water column as well as deepened nutricline.

1. Introduction
Sulawesi is one of the most interesting places for investigated. its K-shape which was the result of the collision of the cratonic Asia with the micro continent causing this region have complex geological condition. An example of this unique area is the western arm of Sulawesi has a different geological framework to the east (figure 1). The Tertiary sediment is widespread on the western Sulawesi, and Tonasa limestone is one of the most thickness of the sedimentary rock, which composed by coral limestone, bioclastic limestone and marl interbedded, and redeposit limestone [1],[2]. Previous study suggest that the Tonasa limestone deposited on relatively stable shallow-water, known as the Tonasa carbonate platform [2], many authors have conducted research on the Tonasa Formation, such as lithology in general, stratigraphic sequence, and biostratigraphy of foraminifera, however no studies of calcareous nannofossil. The detail foraminifera study correlated with the paleotemperature also conducted in Palakka area [3].

In this paper we results investigation of calcareous nannofossil assemblages from the limestone and marl interbeds of Barru River section. And the purpose of this research are to analyze correlation between the assemblages of calcareous nannofossil and their implication to paleoenvironmental
identification. This is a preliminary study of calcareous nannofossil in this area, therefore the investigation has not been in quantitative research.

Many authors have made it clear that calcareous nannofossils have broader applications, as well as good tools for paleoenvironmental analysis, age determination, including paleoecologic and paleoclimatic conditions [4, 5, 6, 7, 8]. The quantitative research of calcareous nannofossils have also conducted, for instance its relationship with productivity [7, 9,10,11]. Discoaster species abundantly in the Paleogene to Neogene intervals and had been interpreted as a typical warm water species [12].

2. Geological Setting

Sulawesi Island has been complex tectonic in the world, which is situated at junctio three major plate which an almost complete Tertiary sequence [16]. The Tertiary carbonate was developed extensively in Southeast Asia, one of which is the Tonasa Formation with a thickness of up to thousands of meters. Interbeds of the limestone and marl are well exposed in Barru River and surrounding areas. Tonasa Limestone Formation extends from the north of Barru area to the Jeneponto in the south. The Tonasa Formation is a deposit of carbonate rock from the late Eocene to the Middle Miocene [1], moreover this formation was deposited as a shallow - water and outer ramp / endinal precipitate of the carbonate platform, particularly in the Pangkajene and Jeneponto area [17].

Stratigraphically, Balangbaru Formation is the oldest sedimentary rock unconformably overlies the basement complex of the western, which composed by deep marine sediments, Overlying of Balangbaru Formation is angular unconformably of Mallawa Formation that characterized by deposits of marginal transitions from Paleocene age, and it is overlain by carbonate deposits, formed initially a transgressive sequence [1, 17, 18]. The study area is located at Barru River, Barru Regency South Sulawesi Province (figure 1). This area consists of interbedded carbonate rock deposits.

![Figure 1](image-url)

**Figure 1.** Lithotectonic setting of Sulawesi Island and Geological map of South Sulawesi (after [1,2,18,19] modified)
3. Samples and Methods
Samples used in this study we collected from the outcrop of Barru River with measuring section method. A total of 40 layers of marl and limestone interbeds from this section were taken to be analyzed nannofossils. All samples were processed by the smear slides method. As much as 100-300 grams of dried sediment are made into powder, then a small sample is sprinkled on a 24 x 24 mm glass cover and dripped with water using a pipette. The samples were flattened on all cover glass surfaces using a toothpick and then dried on a hot plate at 70 ° C. Then observed species and taken nannofossils photographed under a light microscope with 1000x magnification. In order to describe the assemblages of nannofossil we identified all species across all slide view.

4. Results
Barru area is one of the locations where Tonasa limestone is well exposed, and the Barru River section shows marl and limestone interbeds and is a good for stratigraphic measuring section (figure 2). Marl dominated in this section with thickness of layers 1.5 – 40 cm, and thickness of limestone around 1 – 60 cm. Strike/dip of layers generally have orientation N 325°E/34°. Length of the measuring section is 353.96 meter and total thickness is around 23 m.

![Figure 2. Photograph of outcrop between marl (X) and limestone (Y) interbeds in Barru River](image)

4.1. Distribution of Calcareous Nannofossils
The distribution of Calcareous nannofossils from bottom to the top of the Barru River section shown that species are increasingly diverse, while discoaster are almost found in each layer. The photographs from the selected taxa are illustrated in figure 3 and figure 4. Generally, calcareous nannofossils in this section is fairly abundant and moderately preserved, however some samples are poorly preserved. There are 2 layers of 40 layers that are not found nannofossils, this may be due to the diagenesis processes in limestone. As many as 15 genera and 25 species are found,

Reworked specimens have been identified from this section, they are mainly Paleocene – early Eocene age. The presence of this species may be due to the transport of sedimentary material from older sedimentary rocks. This fact indicates that there was marine sedimentary rock older than the Tonasa Formation.
Figure 3. Photomicrograph of nannofossils all in CN (Cross Nicol), 1a,b. Braarudosphaera bigelowii (Gran & Braarud) Deflandre, 2. Cyclicargolithus abisectus (müller) Wise, 3. Dictyococcites bisectus (Hay, Mohler & Wade, 1966) Bukry & Percival (1971), 4. Pontosphaera enormis Locker (1967) Perch-Nielsen (1984a), 5. Sphenolithus predistentus Bramlette & Wilcoxon (1967), 6. 7, Sphenolithus distentus (Martini, 1965) Bramlette & Wilcoxon (1967), 8.9.10.11.12, Sphenolithus pseudoradians Bramlette & Wilcoxon (1967), 13. Zygrhablithus bijugatus (Deflandre in Deflandre & Fert, 1954) Deflandre (1959), 14. Calcidiscus protoannulus (Gartner, 1971) Loeblich & Tappan (1978), 15. Dictyococcites sp., 16.17. Dictyococcites scrippssae Bukry & Percival (1971), 18. Reticulofenestra umbilica (Levin, 1965) Martini & Ritzkowski (1968), 19. Cribrocentrum reticulatum (Gartner & Smith, 1967) Perch-Nielsen (1971d).
Biostratigraphy

The age of the sample studied from a total of 25 calcareous nannofossil species was determined from the First Occurrence (FO) and Last Occurrence (LO) of marker species, and based on the result identified marker species, they are FO of *Sphenolithus pseudoradians* Bramlette & Wilcoxon, LO of *Discoaster saipanensis* Bramlette & Riedel, FO of *Markalius inversus* (Deflandre in Deflandre & Fert, 1954) Bramlette & Martini (1964), LO of *Chiasmolithus altus* Bukry & Percival (1971), FO of *Dictyococcites bisectus* (Hay, Mohler & Wade) Bukry & Percival, and the LO of *Zygrhablithus bijugatus* (Deflandre) Deflandre, therefore the age of rocks in the Barru River outcrop was determined by according to the first and last occurrence of marker species based on the standard zonation of Martini [20] is NP 16 – NP 24 and standard zonation by Okada and Bukry [21] is CP 14a – CP 19a or age equivalent as the Middle Eocene to Oligocene.

Figure 4. Photomicrograph of nannofossils: CN (Cross Nicol), PN (Parallel Nicol), 1,2. *Cribrocentrum reticulatum* (Gartner & Smith, 1967) Perch-Nielsen (1971d), CN, 3. *Ellipsolithus macellus* (Bramline & Sullivan, 1961) Sullivan (1964), CN, 4,5,6. *Coccolithus eopelagicus* (Bramlette & Riedel, 1954) Bramlette & Sullivan (1961), CN, 7. *Coccolithus pelagicus* (Wallich, 1877) Schiller (1930), CN, 8. *Helicosphaera* sp., CN, 9. *Markalius inversus* (Deflandre in Deflandre & Fert, 1954) Bramlette & Martini (1964), CN, 10. *Chiasmolithus altus* Bukry & Percival (1971), CN, 11. *Discoaster saipanensis* Bramlette & Riedel (1954), PN, 12. *Discoaster saipanensis* Bramlette & Riedel (1954), CN, 13. *Discoaster barbadiensis* Tan (1927), CN, 14. *Discoaster sublodoensis* Bramlette & Sullivan (1961), CN, 15. *Discoaster deflandrei* Bramlette & Riedel (1954) PN, 16. *Discoaster* sp.
4.3. **Paleoenvironmental Analysis**

The presence of some species indicating specific environments could be identified. Paleoenvironment of Palakka area especially upstream of Barru River Section is reconstructed based on calcareous nannofossils data. From the results of the identification of nannofossils, Discoaster species are found in almost every rock layer, the presence of these species as typical warm water that lived in the low photic zone.

A living nannofossil species, such as *Florisphaera profunda*, presently found in lower photic zone, which is a proxy to reconstruct the stability of the Quaternary sea surface condition with nutricline and thermocline. This specimen is not found in the Pliocene to older age, therefore it is difficult to reconstruct the sea surface conditions during the Neogene. Instead it was Discoaster that lived on Paleogene to Neogene (Tersier).

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