Paleoclimate prediction based on *Discoaster* occurrence in Walanae Sandstone of South Sulawesi

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**Abstract.** The Walanae Formation is the youngest sedimentary rock that formed a mountainous area along the Walanae River Valley. It is very interesting and challenging to prove that Walanae Depression developed from the Late Miocene to the Late Pliocene. This area gradually became a marine environment and how the climatic conditions at that time were particularly on the Salo Mario section. Soppeng Regency. Measuring section on Salo Mario obtained 32 layers, consists of interbedded claystone, sandstone, and conglomerate on the upper part of the outcrop. Samples from the layers are then made into smear slides and dried using a UV lamp, and the preparations were analyzed under a microscope at a magnification of 1000x. The result of laboratory observations, nannofossil is only found in 11 layers consisting of coccolith and Discoaster. The nannofossils found are namely *Discoaster* asymmetricus Gartner, *Discoaster* berggrenii Bukry, *Discoaster* bollii Martini and Bramlette, *Discoaster* brouweri Tan Sin Hok, *Discoaster* calcaris Gartner, *Discoaster* deflandrei Bramlette and Riedel, *Discoaster* neohamatus Bukry and Bramlette, *Discoaster* pentaradiatus Tan Sin Hok, *Discoaster* pseudovariabilis Martini and Worsley, *Discoaster* surculus Martini and Bramlette, *Discoaster* tamalis Kamptner, *Discoaster* triradiatus Tan Sin Hok, and *Discoaster* variabilis Martini and Bramlette. The occurrence of the *Discoaster* indicates the warming of the lower photic zone caused by the weakening of upwelling.

1. Introduction
The southern arm of Sulawesi is part of the Sundaland [1,2] which was cut by the Walanae Fault, that moved relatively north-south and formed the Walanae Depression [3–5], whereupon the Walanae Depression was likely developed during the Late Miocene then filled with sediments, pyroclastics, and volcanic formed the Walanae Formation. At first, this area was a marine environment that gradually became marginal at the end of the Pliocene.

The Walanae Formation is the youngest of the sedimentary rock associations from Late Miocene to Pliocene, which spread from the north in Pare-Pare to the south of Selayar Island (Figure 1).
Much detailed research is needed to find out the geological history of Walanae depression and later to become a basin where the Walanae Formation was the widespread deposition of clastic sediments interbeds, and the aim of this study conducted was to determine the *Discoaster* assemblages as one of the main characteristics of paleoclimatic condition.

Coccolithophores play a primary role in the global carbon cycle [6]; thus, most calcareous nannoplanktons was a significant component phytoplankton inhabitant at different levels of the photic zone that reflects the surface water condition [7,8].

*Discoaster* spp is low latitude marker species [9], which indicated as lower-photic zone species, which have similar characteristics with *Florisphaera profunda* [8,10–12]. *Discoaster*, which last appeared in 2.0 Ma [13].

2. **Materials and methods**

As many as 32 samples from the Salo Mario (Salo means River) section were analyzed (Figure 2). Smear slides were prepared after the sediment was crushed to powder and ready to be analyzed under a microscope at 1000 x magnification. After that, the number of *Discoasters* was examined and scanned other species as they present. In the research area, the nannofossil is not well preserved. As a result, the number of nannofossils is very scarce, subsequently the calculation of *Discoaster* and scanning the presence of other nannofossils by the semi-quantitative methods.
3. Geological background
There is no detailed study of the Walanae Formation until [4,5] conducted a regional geological mapping and named "Walanae Formation" for clastic sediments and volcaniclastic interbeds. The event was initiated by the end of the volcanism period followed by tectonics, which led to the beginning of the Walanae Graben, which later became the basin where Walanae Formation was formed. This event most likely took place from the beginning of the Middle Miocene to Pliocene.

The two mountain belts are separated by a graben-like structure that is known as the Walanae Depression that controlled by the regional movements of north-south, relatively known as the Walanae Fault Zone [3,4,14,15]. A simplified stratigraphic framework is composed as described below:

The eastern part of the southern arm of Sulawesi, the Salo Kalupang (Teos) Formation, which is estimated to be Early Eocene to Late Oligocene has marine sedimentary facies [4] while the Salokalupang Formation was deposited in a deepwater depositional environment in the Late Eocene to Middle Miocene [16]. The Salo Kalupang Formation occurred to the east, and the Tonasa Formation was deposited on a carbonate platform that occurred within the Middle Miocene to the west of SW Sulawesi. The upper part of Tonasa Formation was unconformably overlain by the Camba Formation deposition in the Middle-Late Miocene, which consists of marine sedimentary rocks and volcaniclastic interbeds (Tmc), thereafter laterally the environment turned into dominant volcanic rocks [5]. During that period, the Camba Formation accumulated in the western of Walanae Depression when the eastern was predominantly occupied by the deposition of Walanae Formation with shallow marine of Taccipi Member [4,17]. This member is equivalent to Taccipi Formation by
Grainge, et. Al and Ascaria [15,18] that was deposited from the Middle Miocene to Pliocene.

4. Biostratigraphic results
Biozolation of Cenozoic Nannofossil has been carried out by previous researchers, such as [19–22]. Biozolation often used in Indonesia is the biozolation by Martini; Okada and Bukry [20,22]. However, most biozolation nannofossils by [20] are recognized for mid-high latitude.

The result of the investigation indicated as many as the 4 (four) datums based on nannofossils zone by Matini [20] as below:

The zonal boundary of NN13/NN14 was determined by the first occurrence of Discoaster asymmetricus, which was examined in layers: 10 and 27. Zone NN14 is characterized by the presence of Discoaster asymmetricus, while the taxon of Catinaster was absent in this zone. Discoaster variabilis also occurs in this zone, as well as Discoaster spp and Coccolithus spp. These taxaons are difficult to identify caused by the fossils already broken and have been diagenetic processes.

Next, zonal boundary NN14/NN15 cannot be defined, caused by the fact that there is no nannofossils datum, moreover some layers from 16 – 20 nannofossils were not found. Zonal boundary NN15/NN16 was determined by the first occurrence of Discoaster surculus was identified in layer 21 and 27. There are no nannofossils identified in layers 16 to layer 20.

The last zonal boundary is NN18/NN19 was determined by the last occurrence of Discoaster brouweri, which was examined in layer 27. Some species also found in this layer, i.e., Discoaster asymmetricus, Discoaster triradiatus, Discoaster surculus, Discoaster variabilis, Discoaster spp., Coccolithus spp.

5. Discoaster as indicator of paleoclimate
Based on laboratory observation, from a total of 32 samples, nannofossil only found in layers 1, 6, 8, 9, 10, and 27, and was predominantly in claystone. The nannofossils content obtained in this outcrop for several species (Figure 3), namely Catinaster calyculus Martini and Bramlette (1), Catinaster coalitus Martini, and Bramlette (2), Coccolithus spp. (3), Discoaster spp. (4), Discoaster asymmetricus Gartner(5), Discoaster brouweri Tan Sin Hok (6), Discoaster challenger Martini & Riedel (7), Discoaster deflandrei Bramlette and Riedel (8), Discoaster neohamatus Bukry and Bramlette (9), Discoaster pentaradiatus Tan Sin Hok (10), Discoaster surculus Martini and Bramlette (11), Discoaster triradiatus Tan Sin Hok (12), and Discoaster variabilis Martini and Bramlette (13).

Figure 3. Coccolith assemblages from Salo Maio Section.
**Discoaster** is found in all layers containing nannofossil (Table 1), whereas *canaster* is only found in layers 1, 6, 7, and 8, as well as *coccolith* only in 6 layers. However, it cannot be identified because the condition is broken.

As a result of the amount of coccolith and Discoaster, it appears that the Discoaster is diverse than coccolith and appears in almost all nannofossil layers found. This showed that the occurrence of Discoaster in the study area indicated a warm water environment. It is relevant to the results of previous researchers, that the Discoaster is a typical species for the photic zone environment, in the low latitudinal region.

The relationship between the size changes of coccolith and Discoaster abundance and described the changes in the stability of the sea surface conditions [23–25]. In this case study, the coccolith size was not carried out because the numbers are very rare. Therefore it can be said that the number of Discoasters more dominant indicates that the sea was in the oligotrophic condition during the Late Miocene to the Pliocene.

### Table 1. Coccolith and discoaster abundance.

| Species                  | Sample No. | 1 | 2 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 21 | 27 |
|--------------------------|------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coccolithus spp.         | -          | 1 | - | - | 1 | - | 2 | 1 | - | 2 | 1 | - | - | - | - |
| Discoaster spp.          | -          | - | - | - | 3 | 1 | 3 | 1 | 1 | - | - | 1 | - | - | - |
| Discoaster deflandrei    | 3          | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Discoaster variabilis    | 2          | - | 2 | - | - | 2 | - | - | - | - | - | - | - | - | - |
| Discoaster brouweri      | -          | - | - | - | - | - | - | - | - | - | - | - | - | 4 | - |
| Catinaster calyculus     | 1          | 1 | 1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| Catinaster coalitus      | -          | - | 1 | - | - | - | - | - | - | - | - | - | - | - | - |
| Discoaster neohamatus    | -          | - | - | - | - | - | - | - | - | - | - | - | - | - | 3 |
| Discoaster pentaradiatus | 3          | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Discoaster challenger    | -          | - | - | - | - | - | - | - | 1 | - | - | - | - | - | - |
| Discoaster asymmetricus  | -          | - | - | - | - | - | - | - | - | - | - | - | - | 2 | 1 |
| Discoaster aurculus      | -          | - | - | - | - | - | - | - | - | - | - | - | - | 1 | 3 |
| Discoaster triradiatus   | -          | - | - | 2 | - | - | - | - | - | - | - | - | 1 | - | 3 |

#### 6. Conclusion

The Walanae Formation filled the Walanae Depression since the Late Miocene and took place in the marine environment, indicated by the presence of nannofossils. The condition of the seawater at that time was characterized by variations and dominance of the Discoaster, although the number was very scarce in all layers so that the basin was in the warm water temperature and oligotrophic conditions.

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