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PALEOSALINITY CONDITIONS ON LATE MIOCENE–PLEISTOCENE IN THE NORTH EAST JAVA BASIN, INDONESIA BASED ON NANNOPLANKTON POPULATION CHANGES

Kondisi Paelosalinitas pada Miosen Akhir–Pleistosen di Cekungan Jawa Timur Utara, Indonesia, Berdasarkan Perubahan Populasi Nanoplankton

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ABSTRACT Quantitative biostratigraphy analysis by observing *Sphenolithus abies* and *Helicosphaera carteri* could predict paleosalinity changes at a sedimentary basin diachronically. Hyposaline conditions can be investigated from the abundance changes of *Helicosphaera carteri* and *Calcidiscus leptoporus* counts. Along this line, the increasing number of *Sphenolithus abies* demonstrates particular states of normal saline. Paleosalinity changes in the North East Java Basin, from Late Miocene to Pleistocene were identified from the top of Wonocolo Formation to bottom of Ledok Formation. Paleosalinity along this episode was interpreted as hyposaline condition. While at the top of Ledok Formation to Mundu Formation, paleosalinity had changed to normal saline. Furthermore, environment conditions return to hyposaline when Selorejo Formation sediment was deposited. And during the deposition of Lidah Formation, deposition environment had returned to the normal saline.

Keywords: paleosalinity, quantitative biostratigraphy, *Helicosphaera carteri*, *Sphenolithus abies*

ABSTRAK *Analisis biostratigrafi kuantitatif dengan mengamati keberadaan spesies* Sphenolithus abies *dan* Helicosphaera carteri *dapat digunakan untuk mengungkap perubahan salinitas purba pada suatu cekungan pengendapan. Kondisi air laut yang hyposaline dapat diketahui dari perkembangan spesies* Helicosphaera carteri *yang berlimpah. Sebaliknya, peningkatan jumlah* Sphenolithus abies *akan menunjukkan bahwa lingkungan berada pada kondisi salinitas normal. Dengan mempergunakan asumsi yang sama, maka perubahan salinitas di daerah penelitian yang termasuk ke dalam Cekungan Jawa Timur Utara, pada Kala Miosen Akhir hingga Plistosen, dapat diinterpretasikan sebagai berikut. Formasi Wonocolo bagian atas hingga Formasi Ledok bagian bawah, air lautnya dinterpretasikan memiliki kondisi hyposaline. Sedangkan pada Formasi Ledok bagian atas hingga Formasi Mundu, lingkungan berubah menjadi kondisi*

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salinitas normal. Selanjutnya, kondisi lingkungan berubah menjadi hyposaline kembali ketika diendapkan Formasi Selorejo. Sedangkan pada saat pengendapan Formasi Lidah, lingkungan berubah dan kembali pada kondisi salinitas normal.

Kata Kunci: *salinitas purba, biostratigrafi kuantitatif, Helicosphaera carteri, Sphenolithus abies*

INTRODUCTION

An assumption that the changes in the environment will always be accompanied by changes in the organism has been widely accepted. Therefore by looking at the changes in the number of organisms living in an environment, we can also learn the changes of the environment. Melinte (2004) and Bour et al ., (2007) discussed the nannoplankton as indicators for environmental change. Thereafter, Wade and Brown (2006) also pointed out that the nannoplankton species can be used as indicators of environmental changes, particularly salinity, in the area of Cyprus. They discussed the existence of the species *Sphenolithus abies* and *Helicosphaera carteri* and their relationship with the water salinity conditions, where both species were found. The results of Melinte's study (2004) suggested that *Calcidiscus leptoporus* lives in hyposaline conditions. While Wade and Brown (2006) concluded that in the Polemi Basin, Cyprus, *Helicosphaera carteri* is abundant in hyposaline condition. Therefore, an increasing number of environmental *Sphenolithus abies* manifests normal saline condition. Considering those previous studies, we applied the methods used by Melinte (2004) and Wade and Brown (2006) to investigate paleosalinity condition in North East Java Basin.

Regional Geology

The study area was the North East Java Basin, in the area of Gunung Panti, Pati District, Central Java Province (Figure 1) at coordinates of 06º 52' 30"- 06º 54'09" Latitude and 111º 03' 00"- 111° 05'30" E Longitude. North East Java Basin was selected because Plio – Pleistocene sediments in this basin was deposited in marine environment. Paleosalinity changes can be traced from marine deposits, which its deposition environment was suitable for nannoplankton's life.

Based on the Physiographic Map of East Java, Gunung Panti area belongs to the Rembang Zone (Figure 1). According to previous regional mapping by Kadar & Sudijono (1993), formations exposed in this area were Wonocolo, Ledok, Mundu, Selorejo and Lidah Formation (Figure 2). Wonocolo Formation consists of claystone intercalated by limestones. Ledok

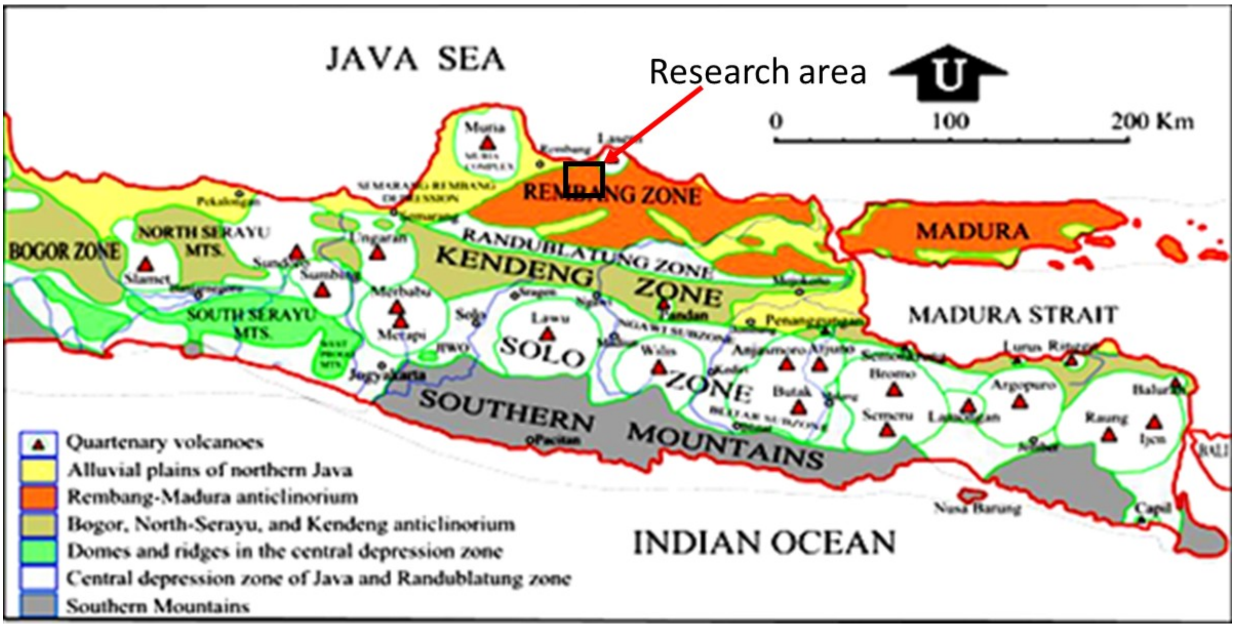

Figure 1. East Java Physiographic Map. Research area in black box. (van Bemmelen, 1949).

Formation is characterized by coarse sandstone with limestone intercalation. Mundu Formation is featured by marls with limestone intercalated. Selorejo Member signifies grainstone limestone with mollusc fragments (de Genevraye and Samuel, 1972; Insani, 2011). Based on the more recent study, the name of Selorejo Member changed to

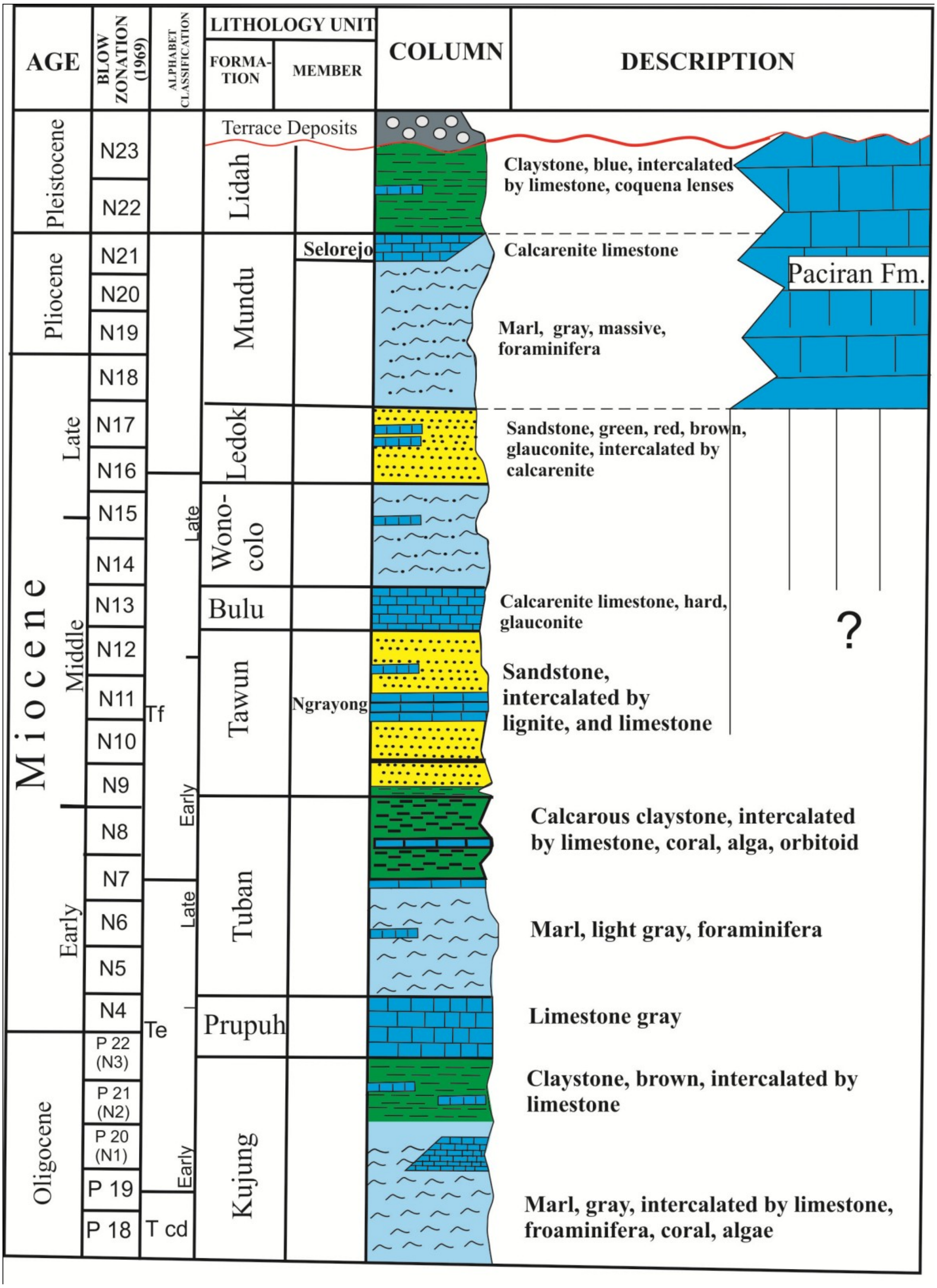

Figure 2. North East Java Basin Stratigraphic Column (Pringgoprawiro, 1983).

Selorejo Formation (Pringgoprawiro, 1983; Sribudiyani et al., 2003). The youngest formation of Lidah Formation, displays sort of bluish massive mudstone.

METHODS

In the North East Java Basin, measuring section performed at three traverses, namely Sungai Kedunglawah Traverse, Sungai Tambar – Sungai Nggaber Traverse, and Sungai Kedungkembang Traverse (Figure 3). Samples collected were from of Upper Miocene to Pliocene. Nine samples were gathered from Sungai Kedunglawah Traverse, 14 samples were taken from Sungai Tambar – Sungai Nggaber Traverse, while 9 other samples were taken from Sungai Kedungkembang Traverse.

Nannoplankton analysis observations had been accomplished by the commonly-used field of view (FOV) method. Standard-sized cover glass (120 x 250 μm). In one observation of FOV, the number of each species of nannoplankton counted 15 times at different places and then multiplied by eight. The rest of the observations were made to find some species markers that might be found in the sample.

Several fossil indicators used in this research were *Sphenolithus abies, Helicosphaera carteri and Calcidiscus leptoporus Sphenolithus abies* (Figure 4a), which have similar environment with the *Discoaster* genus. Generally, *Sphenolithus* and *Discoaster* live coexistence in oligotrophic environments, warm, open ocean conditions and indicate the environment with normal salinity levels (Wade and Brown, 2006).

The abundant of genus *Helicosphaera* signifies shallow marine environment, which is the zone of upwelling, eutrophic environment. *Helicosphaera carteri* (Figure 4b) indicates hyposaline environmental conditions, eutrophic, and a lot of the shallow marine areas (Wade and Brown, 2006). From the samples taken from the Black Sea, *Helicopshaera carteri* is a species capable of living in salinity under normal conditions (Melinte, 2004). *Calcidiscus leptoporus* (Figure 4c) developed in areas with below-normal salinity conditions. In samples taken from the Black Sea, *Calcidiscus leptoporus* is a species also capable of living in salinity under normal conditions (Melinte, 2004).

RESULT AND DISCUSSION

Sungai Kedunglawah Traverse

Comparison of the development of species *Helicosphaera carteri* and *Sphenolithus abies* at Sungai Kedunglawah Traverse can be observed in Figure 5. On NG-26 samples, which obtained at Wonocolo Formation, there is an appearance of *Helicosphaera carteri*, but not *Sphenolithus abies*. This predicament indicates that on the top of Wonocolo Formation, the environment is in hyposaline condition. This is caused by the shallowing environment, where Bulu Formation gradually had become Wonocolo Formation.

The sample of KD - 09, KD - 07, and KD - 06 that were gathered from Upper Ledok Formation has a trend of increasing numbers of *Sphenolithus abies* and loss of *Helicosphaera carteri*. It shows that when Ledok Formation was deposited, the environment is in normal saline condition.

KB-05 samples were taken on Mundu Formation with the peak of abundance of *Sphenolithus abies* that reaches 4815 counts and the peak of the abundance of *Helicosphaera carteri* that reaches 105 counts. The higher number of *Sphenolithus abies*is than *Helicosphaera carteri* shows that when the Mundu Formation was deposited, the environment was more suitable for the live of *Sphenolithus abies*. It indicates that when the Mundu Formation deposit was accumulated, the environment was in normal saline.

Sungai Tambar - Nggaber Traverse

Comparison of the development of species *Helicosphaera carteri* and *Sphenolithus abies* on the Sungai Tambar – Nggaber Traverse can be observed in Figure 6. The results of the analysis of nannoplankton in Sungai Tambar – Nggaber Traverse expressed the same trend with the results on the Sungai Kedunglawah Traverse.

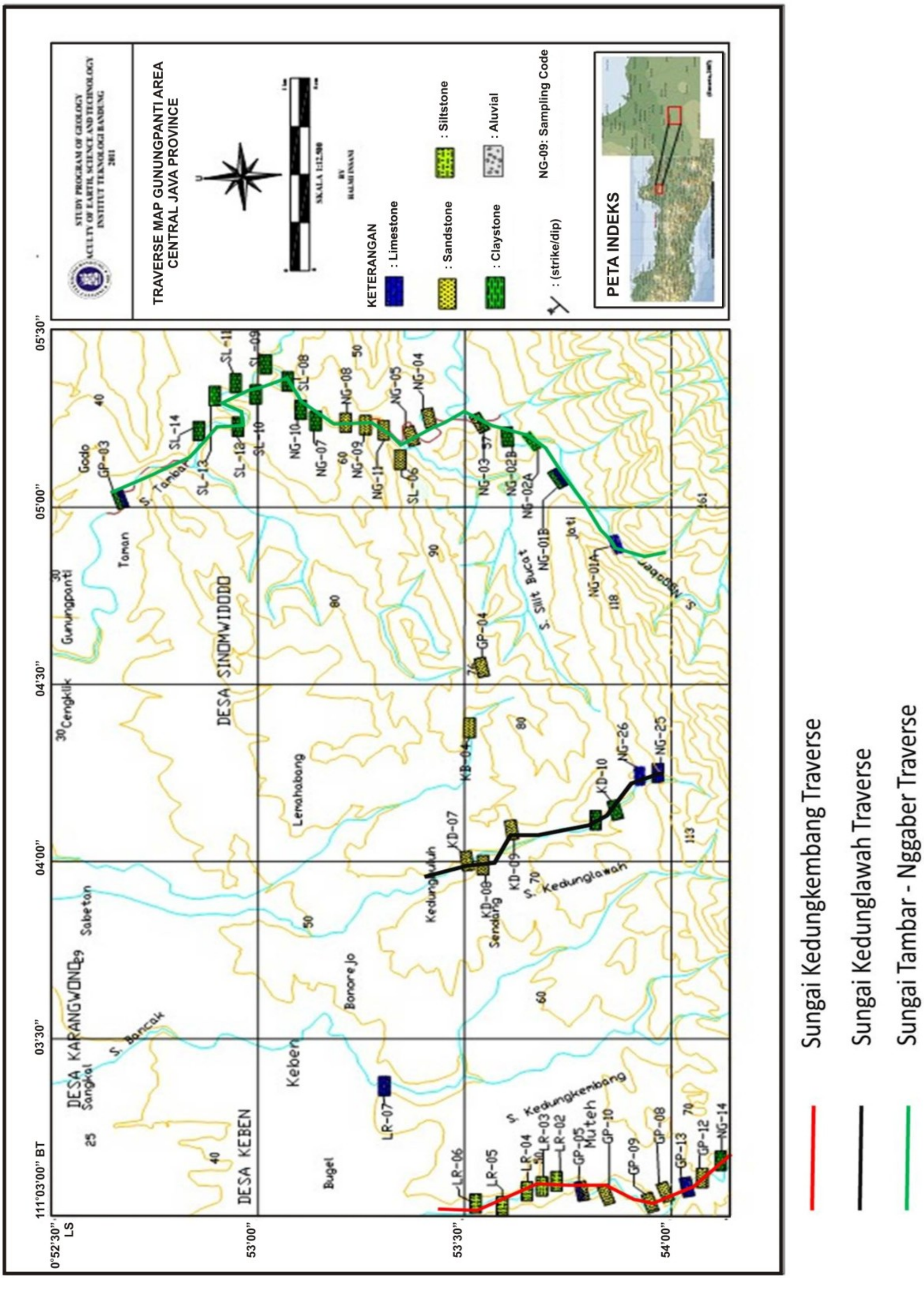

Figure 3 : Traverse and Sampling Map

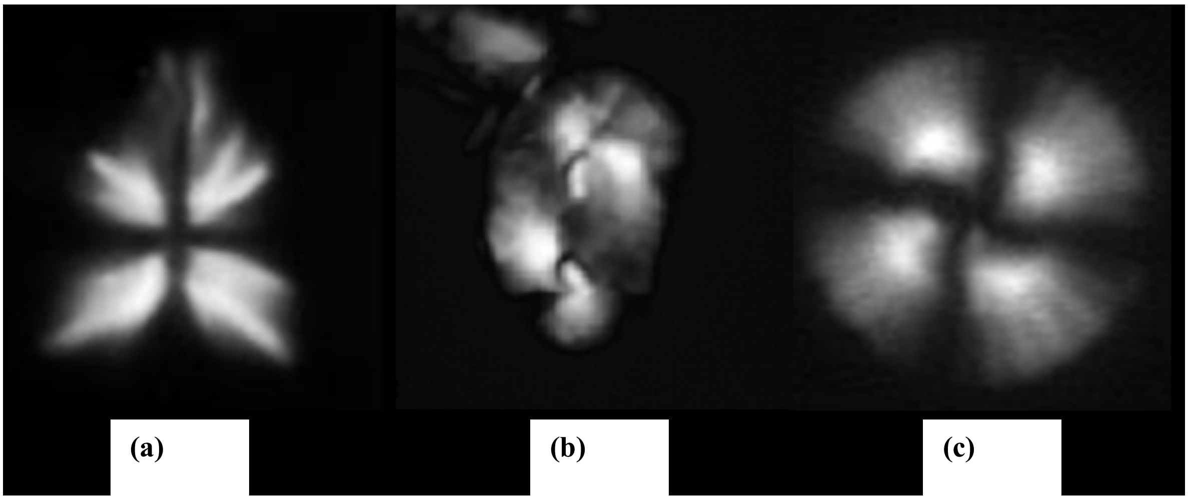

Figure 4. Fossil indicator.

a. *Sphenolithus abies* b. *Helicosphaera carteri* c. *Calcidiscus leptoporus*
(Picture was taken from Young et al., 2011)

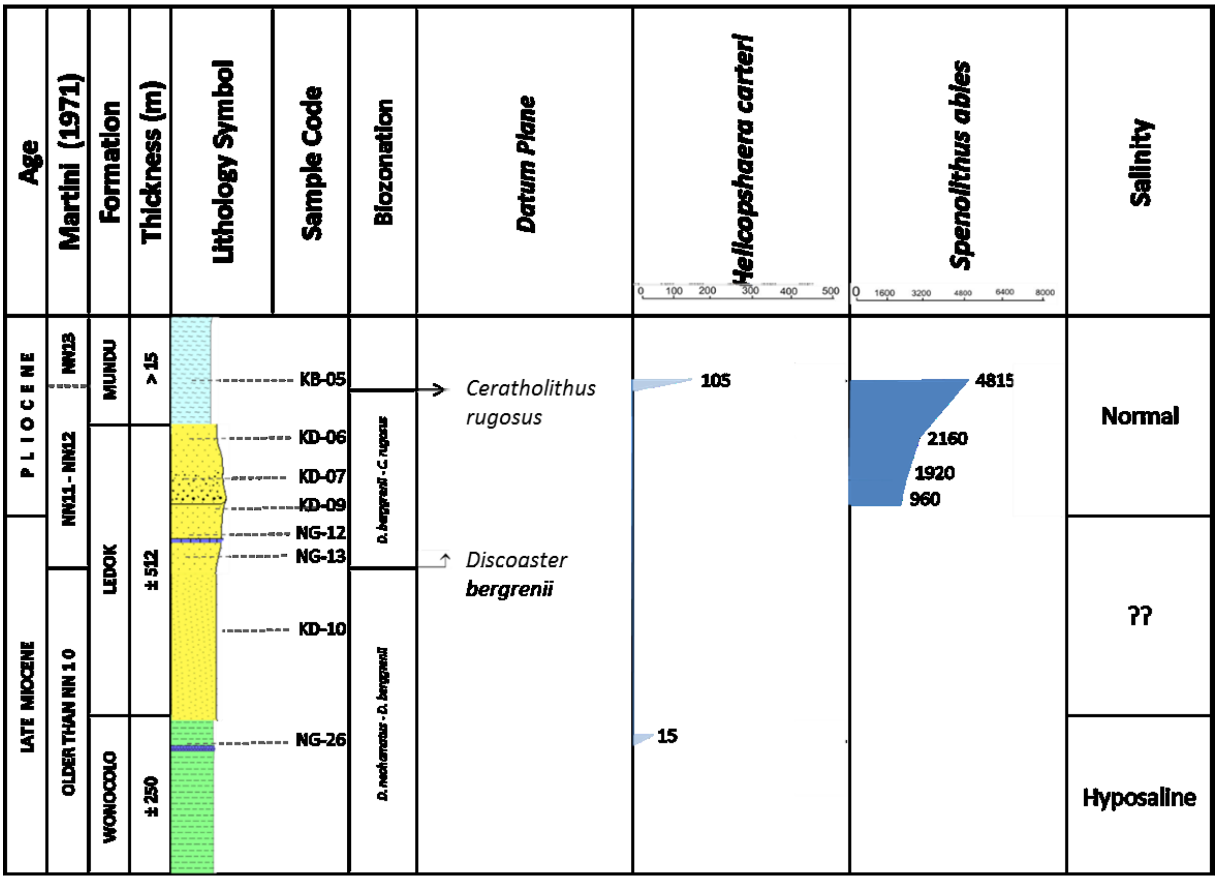

Figure 5. Column of Poppulation Changes *Sphenolithus abies* and *Helicosphaera carteri* in Sungai Kedunglawah Traverse.

From sample of NG-02 (B) that was taken on Wonocolo Formation, there is an appearance of *Helicosphaera carteri*, but not *Sphenolithus abies*. It implies that the top of Wonocolo Formation has environment of hyposaline condition. It is caused by a gradual shallowing environment of Bulu Formation that became Wonocolo Formation.

Sample NG - 04, NG - 05, and SL - 06 were taken from the bottom of Ledok Formation. There is no *Sphenolithus abies* and *Helicosphaera carteri* found in these samples. However, there is a trend of an increasing number of *Calcidiscus leptoporus* species. Based on Melinte (2004), *Calcidiscus leptoporus* lived in hyposaline conditions. NG - 11 NG - 09, and NG - 08 samples were taken from upper of Ledok Formation. There is an increasing trend of *Sphenolithus abies* and loss of *Helicosphaera carteri* in these last samples. Based on *Calcidiscus leptoporus* trend, generally fluctuative population trend can be observed. This can be occured due to transition of salinity change from hyposaline condition to normal saline condition and it made unstable salinity condition.

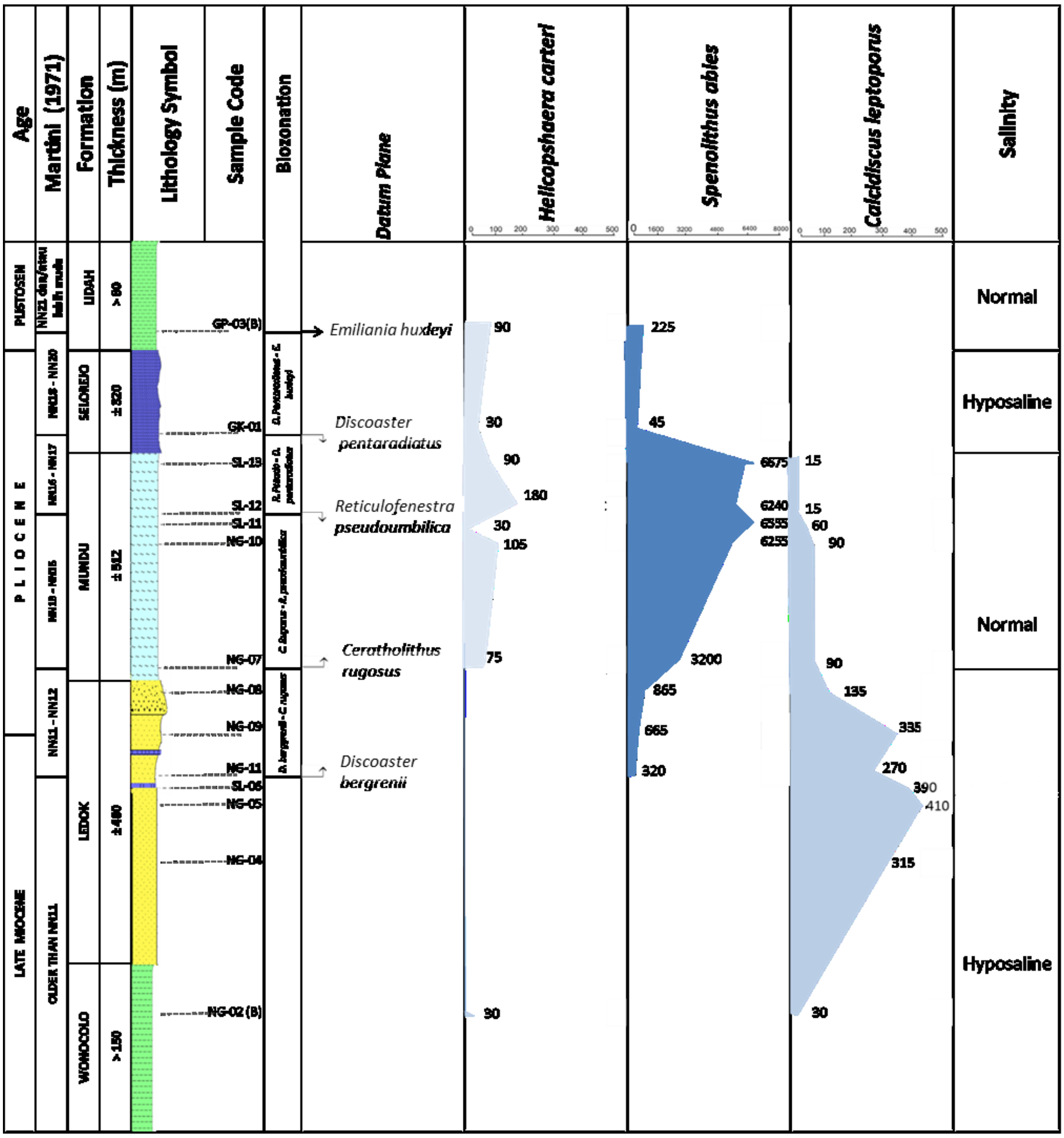

Figure 6. Column of Poppulation Changes *Sphenolithus abies*, *Helicosphaera carteri,* and *Calcidiscus leptoporus* Sungai Tambar – Nggaber Traverse.

Sample NG - 07, NG - 10 SL - 11 SL - 12, and SL - 13 were taken from Mundu Formation. There is a trend of an increasing number of *Sphenolithus abies* and reached a peak at the top of the zone Mundu Formation, which reached 6675 counts. The number of species *Helicosphaera carteri* showed a fluctuating trend. Therefore, in Mundu Formation, the species used to interpret salinity conditions is *Calcidiscus leptoporus*. The development of the species displayed a tendency of decreasing *Calcidiscus leptoporus*. Based on Melinte (2004), *Calcidiscus leptoporus* lives on hyposaline conditions. This event manifested when the Mundu Formation accumulation was deposited in normal saline environment Sample GK - 01 that was taken from Selorejo Formation has the tendency of decreasing trend in the number of *Sphenolithus abies* and *Helicosphaera carteri*. *Sphenolithus abies* falls of 6675 counts in the sample SL - 13 to 45 counts in GK - 01. In the same sample, *Helicosphaera carteri* is down from 90 counts to 30 counts. The declining number of *Sphenolithus abie* demonstrated that when Selorejo Formation sediment was deposited, the environmental condition was not in suitable for *Sphenolithus abies*. This indicated that the Selorejo Formation environment was a very shallow area with hyposaline condition.

At the bottom of Lidah Formation, there is an increase in the number of *Sphenolithus abies* and *Helicosphaera carteri*. *Sphenolithus abies* has increased from 45 to 225 counts. *Helicosphaera carteri* has increased from 30 to 90 counts. This event signifies that when Lidah Formation was accumulated, the environment is suitable for *Sphenolithus abies,* which favourably developed in conditions of normal saline.

Sungai Kedungkembang Traverse

Comparison of the development of species *Helicosphaera carteri* and *Sphenolithus abies* on Sungai Kedungkembang Traverse can be

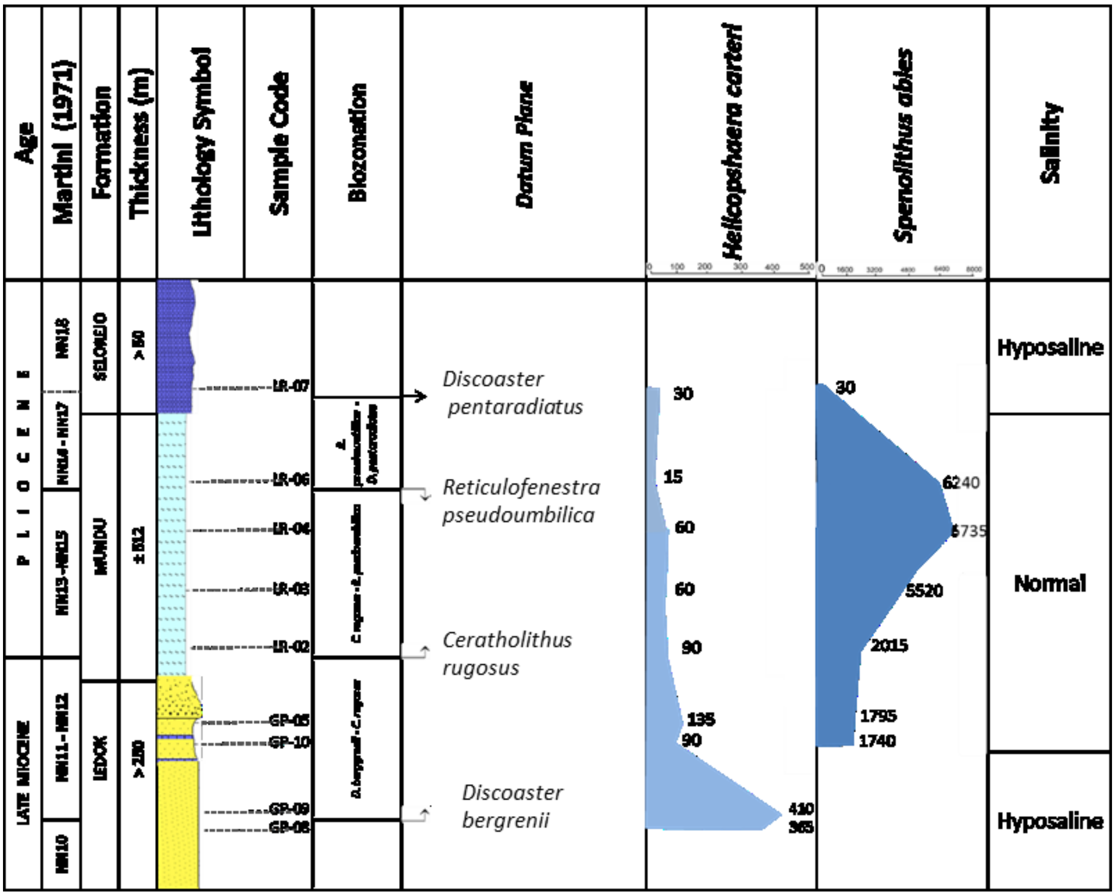

Figure 7. Column of Poppulation Changes *Sphenolithus abies* and *Helicosphaera carteri* in Sungai Kedungkembang Traverse.

observed in Figure 7. Nannoplankton analysis results on the Sungai Kedungkembang Traverse have the same trend with the results on the Sungai Kedunglawah Traverse and Sungai Tambar – Sungai Nggaber Traverse.

In the GP - 08 and GP 09 samples that were taken from the bottom of the Formation Ledok, there is an appearance of *Helicosphaera carteri*, but not *Sphenolithus abies*. It shows that when the bottom of Ledok Formation was deposited, the environment was at hyposaline condition. From GP -10 and GP - 05 samples that were taken from the top of the Formation Ledok, the count of *Helicosphaera carteri* dropped, while the total of *Sphenolithus abies* slightly increased. It shows that when the upper Ledok Formation sediment was deposited, the environment had normal saline conditions.

In sample LR - 02, LR - 03, LR - 04 and LR - 06 that were taken from Mundu Formation, there is a raising number of *Sphenolithus abies*, while *Helicosphaera carteri* number was down. This indicates that when Mundu Formation was deposited, the environmental conditions were suitable for the life of *Sphenolithus abies* in normal saline conditions.

Sample KB - 05 that was taken from Selorejo Formation has drastically low in the *Sphenolithus abies* counts. In sample LR - 06, the count decreased from 6240 to 30. However, a decrease in the number of *Sphenolithus abies* was followed by an increase of *Helicosphaera carteri*. This indicates that the Selorejo Formation environment was at a very shallow area with salinity of hyposaline.

The salinity changes were studied based on the analysis of nannoplanktons. Population of *Spenolithus abies* would increase in normal salinity environtment, but population of *Helicosphaera carteri* and *Calcidiscus leptoporus* would increase in hyposaline environtment. Salinity changes were presented in the salinity curve (Figure 8). In upper part of Wonocolo Formation, sediment was deposited on hyposaline conditions. Hyposaline environment condition continued to the bottom of Ledok Formation. At the top of the Ledok Formation, environment condition was in transition from hyposaline to normal saline condition. However, based on interpretation from Sungai Kedungkembang Traverse, top of Ledok Formation was deposited in normal saline condition. Normal saline condition continued to the top of Mundu Formation. Environment condition turned out to be hyposaline when Selorejo Formation was deposited. In the bottom of Lidah Formation, the environment changed and returned to the normal saline condition.

Salinity condition has not related to lithology, but to depositional environtment. For example, claystone could be deposited in hyposaline condition if it was deposited in the delta or lagoon. However, claystone could be deposited in normal saline condition if it was deposited in open marine.

Based on this study, salinity condition can be interpreted from nannoplankton population changes. However, isotopic analysis, such as ^{18}O isotope analysis, must be done for further verification.

CONCLUSION

Population changes of *Helicosphaera carteri*, *Sphenolithus abies*, and *Calcidiscus leptoporus* could be used to determine the salinity of environment when the sediment was deposited. An increasing number of *Helicosphaera carteri* and *Calcidiscus leptoporus* would indicate the condition of hyposaline environment. And an increasing number of *Sphenolithus abies* would indicate a state of normal saline.

In the North East Java Basin, changes in paleosalinity found from population changes of *Helicosphaera carteri*, *Calcidiscus leptoporus*, and *Sphenolithus abies*. At the deposition of upper part of Wonocolo Formation (NN10), the sediment deposited in hyposaline conditions.

Hyposaline environmental conditions continued until the bottom of Ledok Formation (NN10 - NN 11). In the top of Ledok Formation (NN11 - NN13), the environment condition had returned to normal saline. Normal saline condition continued to the top of Mundu Formation (NN13 - NN17). Environment conditions returned to hyposaline when Selorejo Formation was deposited (NN17 - NN20). In the Lidah Formation (NN21 or younger), environment condition returned to the normal saline condition.

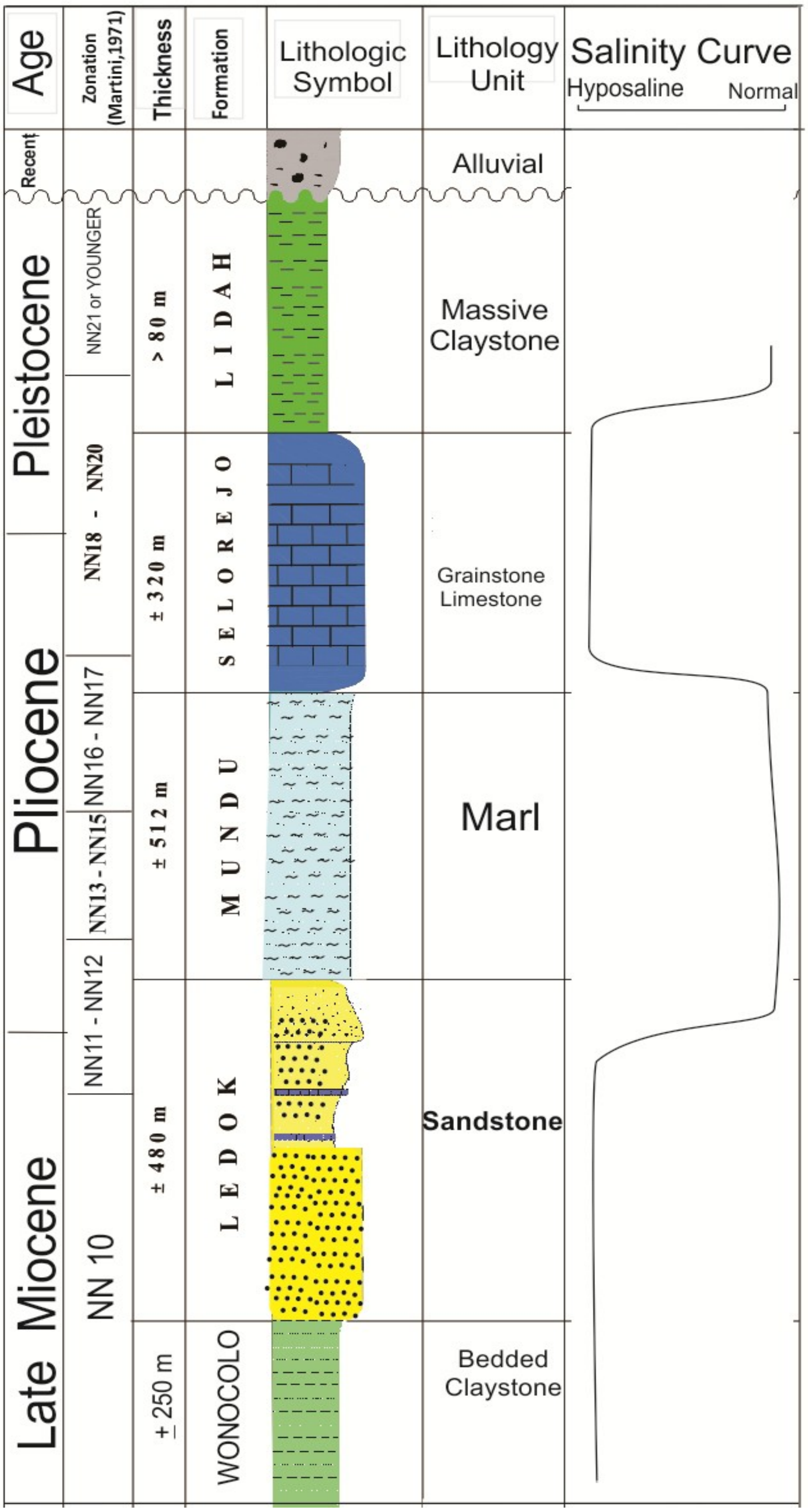

Figure 8. Stratigraphic column and salinity curve changes in North East Java Basin.

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