Biostratigraphy of the Late Miocene Halang Formation in the Loh Pasir succession, Banyumas, Central Java

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ABSTRACT

A detailed biostratigraphic study was conducted to determine the spatial and temporal relationships between the Miocene Halang and Pemali Formations in Central Java. We studied calcareous nannofossils from a 1.4 km thick outcrop section of the Halang Formation at Loh Pasir to document biostratigraphic changes in the Banyumas area. The marine Halang Formation shows three types of lithofacies, predominantly mixed sandy and muddy in the upper part and muddy and sandstone facies in the lower part. We identified 57 species of 13 genera of calcareous nannofossils in 121 samples, which could be divided into five Late Miocene biozones. These zones are Discoaster brouweri, Discoaster hamatus, Discoaster bollii, Discoaster prepentaradiatus and Discoaster quinqueramus. Our results are consistent with previous biostratigraphic work in the Karanggedang 1 well location, except in the lower part of this formation, due to the lack of Catinaster coalitus in the Loh Pasir section.

INTRODUCTION

The Halang Formation is widely distributed in Majalengka towards Banyumas and it consists of sandstone, mudstone, marl, tuff, and minor breccias. In the recent publication of Lunt et al. (2009) the Halang formation was interpreted to unconformably underlie the Pemali Formation. In contrast, previous studies (Kastowo and Sumarna 1996, Asikin et al. 1992, Djuri et al. 1996) indicated the Halang Formation was deposited on the top of Pemali Formation. However, despite the ecent study by Lunt et al. (2009) there is still uncertainty on correlations between continuous records in surface and subsurface sections. Therefore, we will deploy biostratigraphic study on outcrops of the Halang formation in the Banyumas area to correlate with results of core KRG01 from the Pertamina Karang Gedang 1 well.

The age of the Halang Formation was historically estimated between Middle Miocene and Pliocene (Mulhadiyono 1973; Sujanto and Sumantri 1997, Kastowo and Sumarna 1996, Asikin et al. 1992, Djuri et al. 1996). In contrast, Lunt et al. (2009) determined the age of this formation as Late Miocene. A detailed biostratigraphic study of planktonic foraminifera in the Gunung Wetan section in the Banyumas sub-basin was performed by Kadar (1986). First occurrences of *Neogloboquadrina acostaensis* and *Globorotalia plesiotumida* were used as markers for the basal boundary of the Halang Formation, while the upper part of the Halang formation is marked by first occurrences of *Pulleniatina primalis*, followed by first occurrences of *Sphaeroidinella subdehiscens praedehiscens* and *Globoquadrina dehiscens*. This also documented a Late Miocene age for the Halang Formation.
The objectives of this study are to document and illustrate the biostratigraphic record for the Halang Formation in the Banyumas area and to correlate it to the KRG01 cores (Lunt et al., 2009).

MATERIAL AND METHODS

The material of the present work includes 121 samples from the Halang Formation, from a measured section at Kali Pasir (Loh Pasir) in the Banyumas region, located at latitude 108°59'37"E and longitude 7°29'37"S (Figure 1). This is in the Sumatra/Java magmatic arc region, which is bordered in the north by the Northwest Java Basin part and in the south by the Sumatra-Java Fore-arc Basins.

Our lithofacies descriptions follow the Nichols (2009) method for submarine fan facies. Lithofacies were identified from four convenient representative models based on the characteristics and volume of the sediment supplied to the submarine fan. Four representative lithofacies are gravel, sandy, mixed sandy and muddy, and mud.
The calcareous nannofossils were separated from the studied samples, and then identified by using a polarized microscope with x1000 magnification in oil immersion. Photographs of nannofossil were

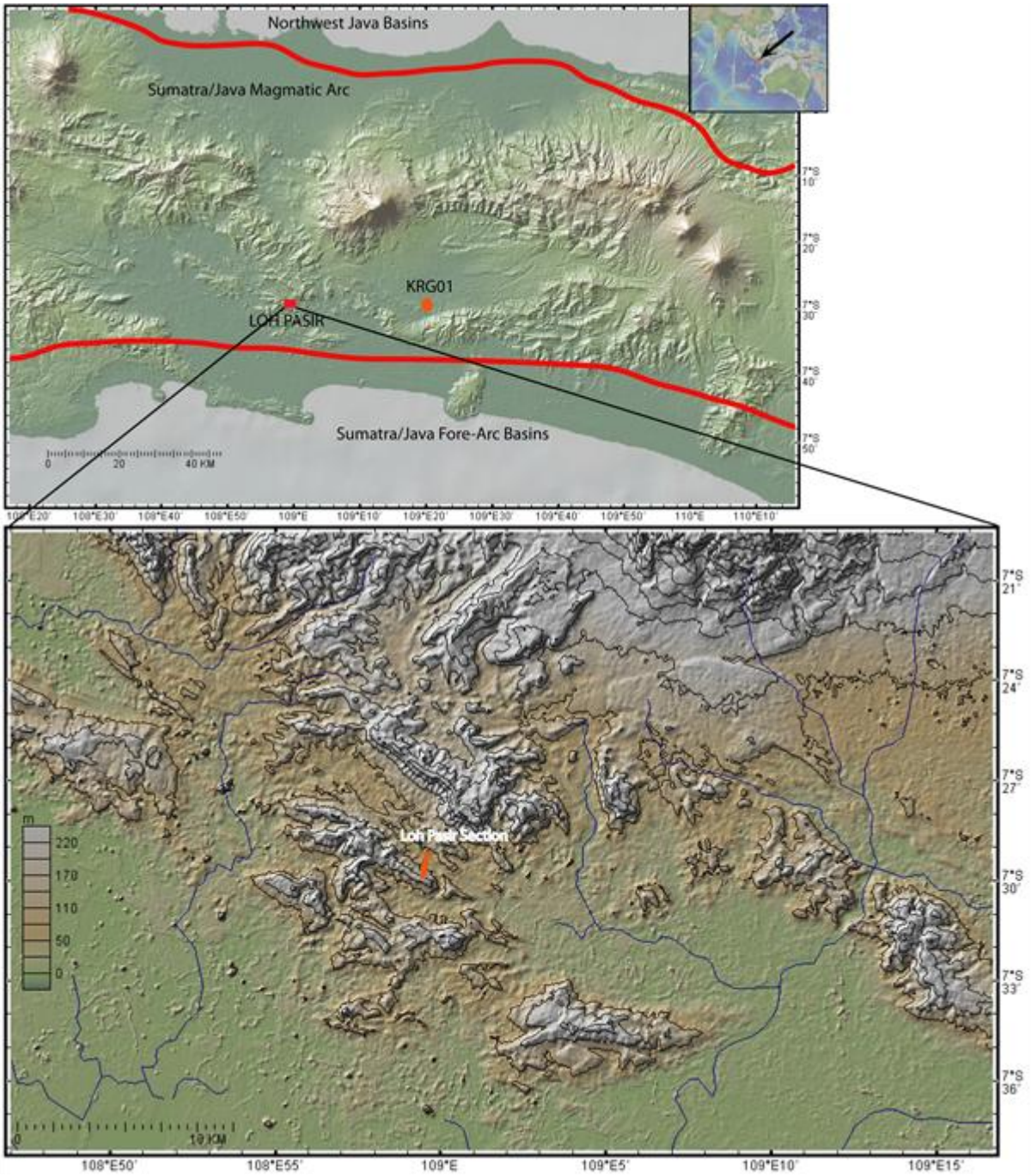


Figure 1. *Loh Pasir section, Banyumas and KRG01 core,e located in the Sumatra-Java magmatic arc. Base map is from United States Geological Survey (USGS) and the interval contour is 100m.*

prepared at the Research and Development Center for Oil and Gas Technology (Lemigas). We used the first and last occurrence datum levels from Martini (1971) and Okada & Bukry (1980) to interpret the biostratigraphic succession in the Halang Formation.

RESULTS AND DISCUSSION

Lithofacies

Lithofacies of Halang formation are dominated by mixed sandy and muddy facies, with relatively minor mudstone and sandstone facies at the bottom part of the Halang Formation (Figure 2).

A. Mixed sandy and muddy facies

The upper part of Halang Formation is composed of mixed sandy and muddy facies of interbedded sandstones and siltstones with some limestone layers. The thickness of this facies is 1040 meters, and is the dominant facies in the Loh Pasir section. This facies is characterized by classical turbidites with some repetitions from the bottom to the upper part of this section. Typical turbidite types in the bottom part include thick sandstone (50-150 cm) with partial Bouma sequences such as Tabc, Tbcd, Tbc, or thin single layer Tc beds. In contrast, the upper parts of this section are dominated by mudstone and thin layers of sandstone (20-50 cm thick), with more single layer Tc and rare Tabc, Tab and Tab Bouma sequences.

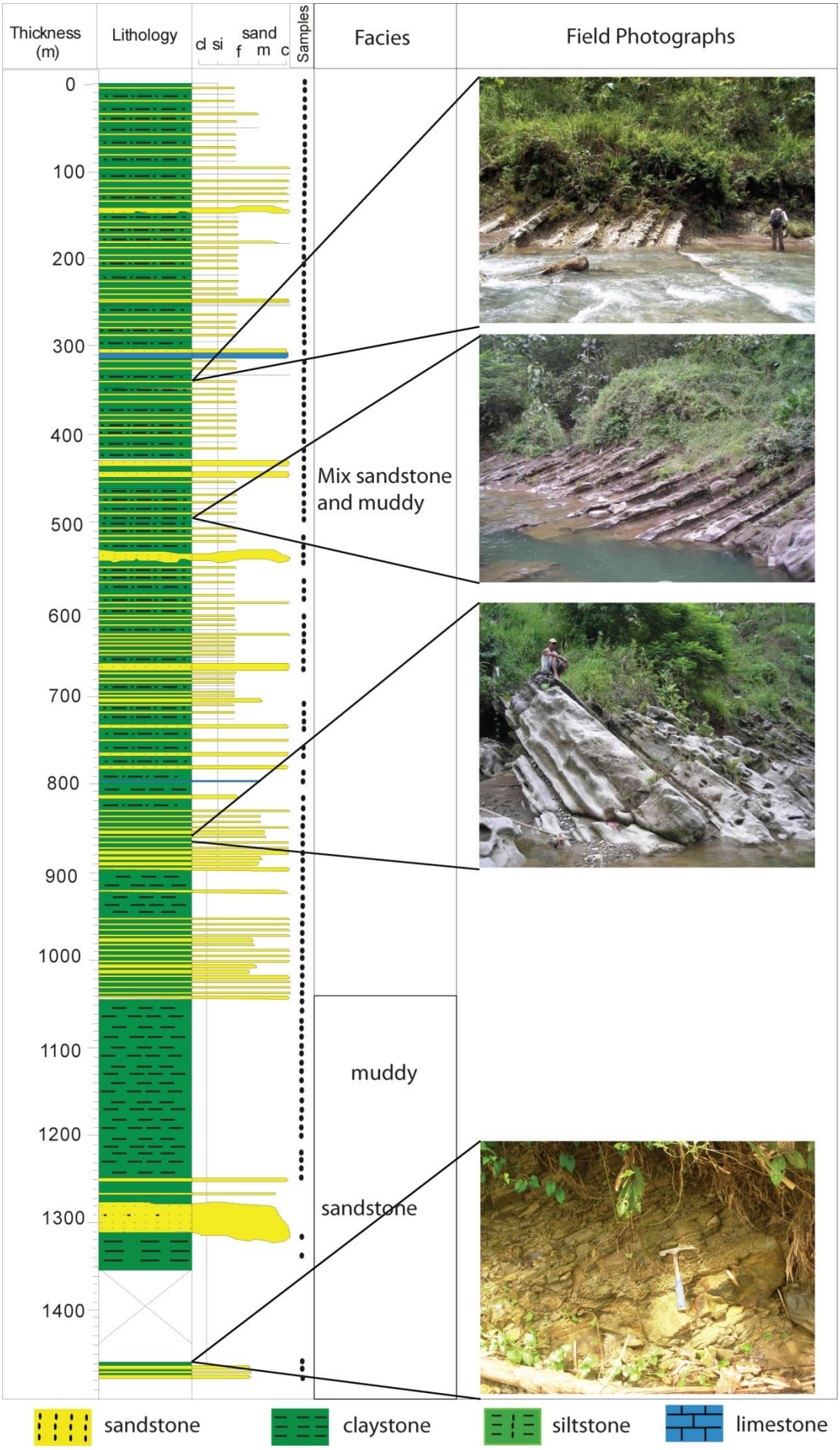


Figure 2. *Lithofacies types of the Halang Formation. Mixed sandy and muddy facies are dominant in the upper part of the formation.*

B. Muddy facies
The Muddy facies consists of claystone and intercalated sandstone (10-20 cm thick) with laminar bedding. The thickness of this facies is 230 m and is near the bottom of the Kali Pasir section.

C. Sandstone facies
The Sandstone facies is in the lowest part of this section with a thickness of more than 40 m. This sandstone is characterized by black sandstone; moreover, with andesitic breccias clasts up to gravel and boulder size and with mud clasts.

BIOSTRATIGRAPHY

We found 57 species of calcareous nannofossils, belonging to 12 genera. The stratigraphic ranges of identified species are given in Figures 3a, b and c.

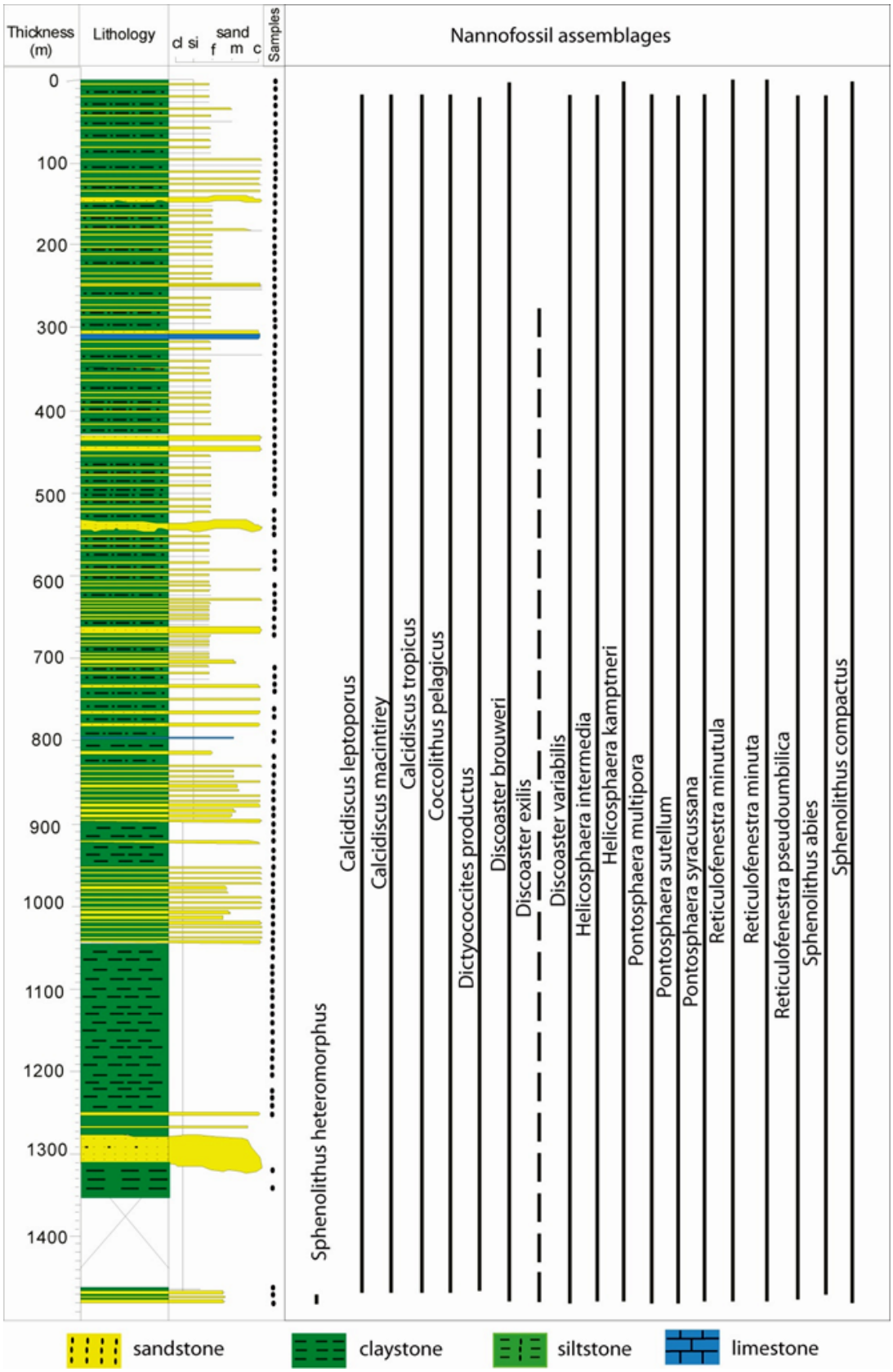


***Figure 3a**. Nannofossil assemblages of Halang Formation in Loh Pasir, Banyumas (1).*

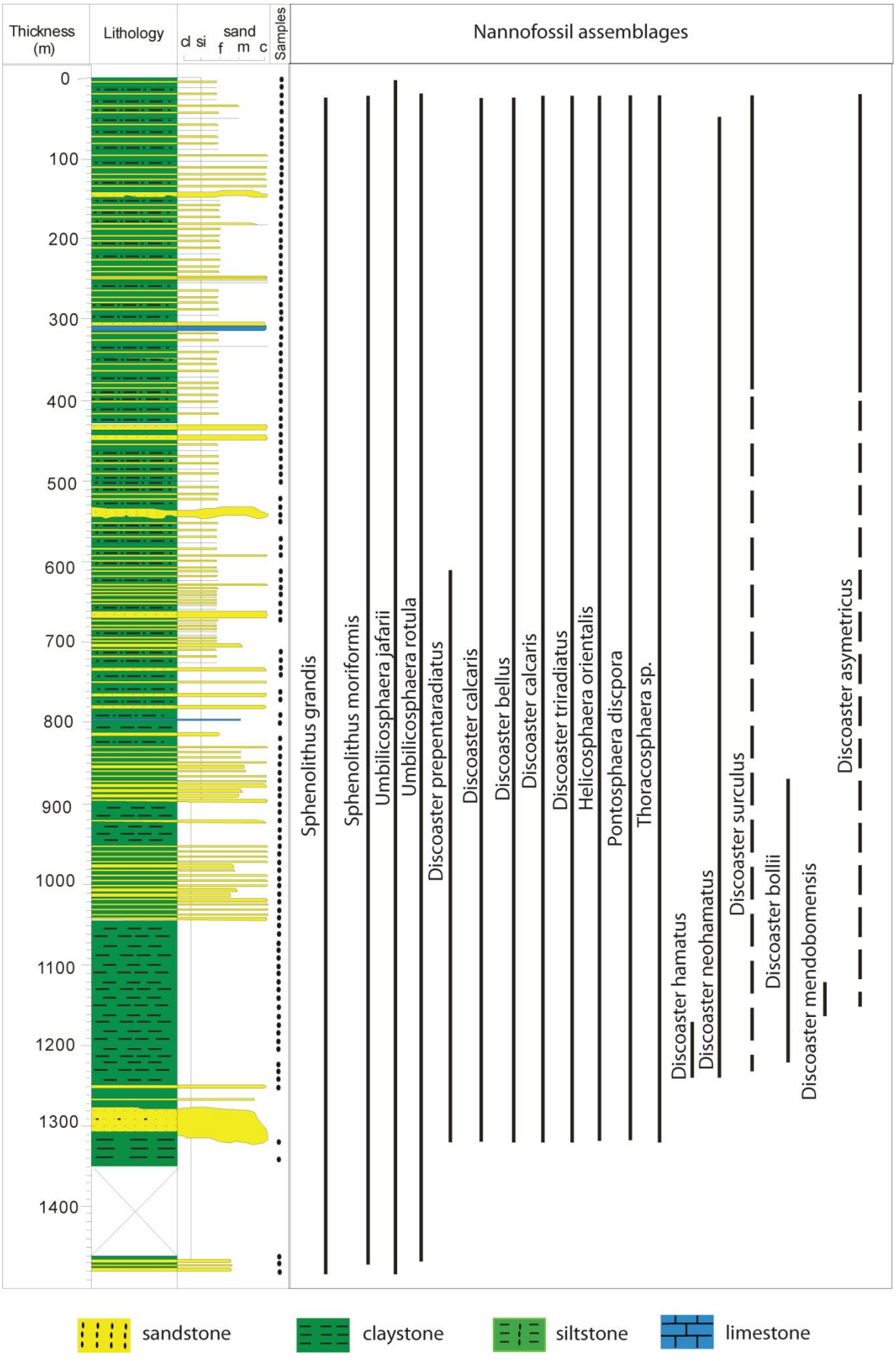


Figure 3b. *Nannofossil assemblages of Halang Formation in Loh Pasir, Banyumas (2).*

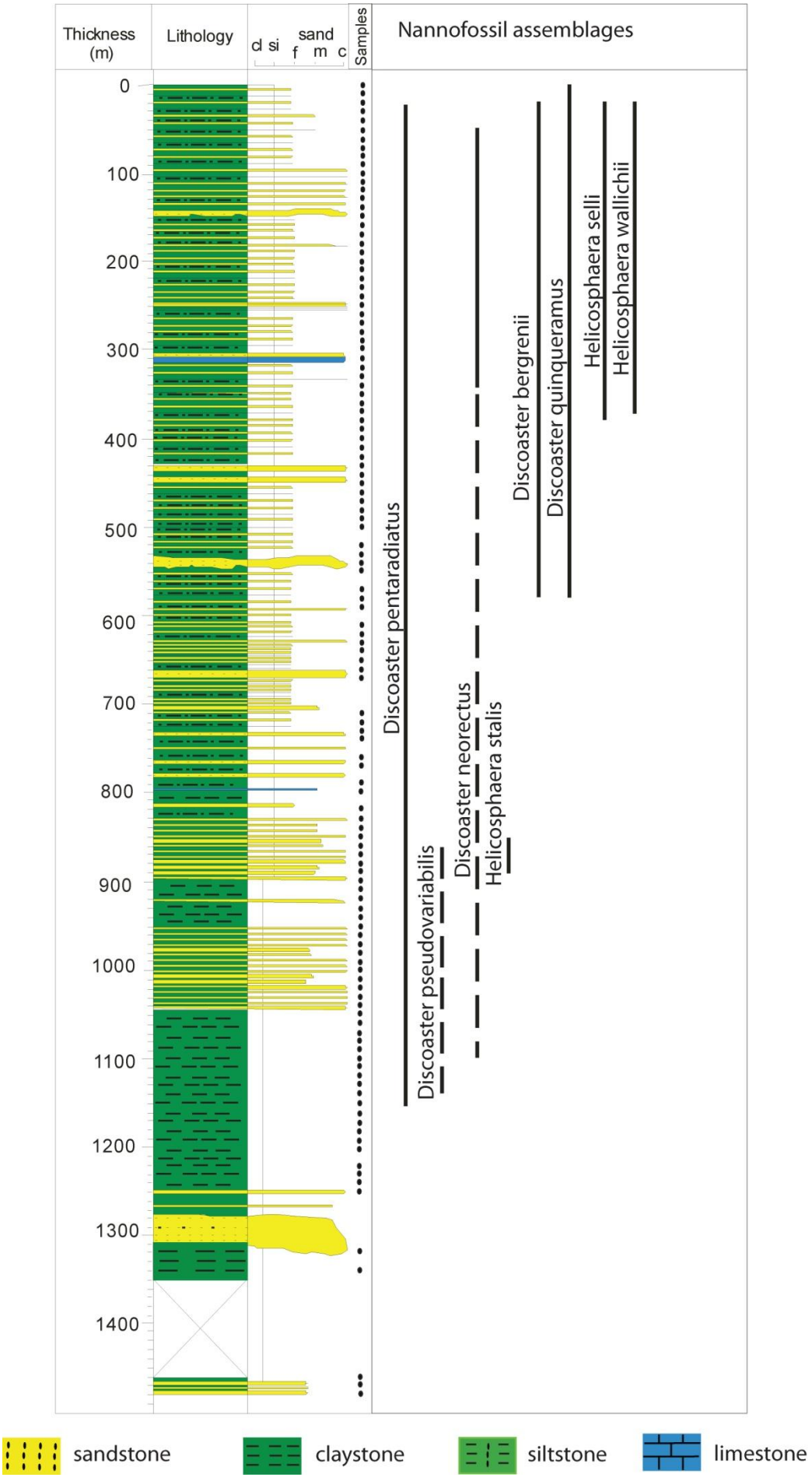


***Figure 3c**. Nannofossil assemblages of Halang Formation in Loh Pasir, Banyumas (3).*

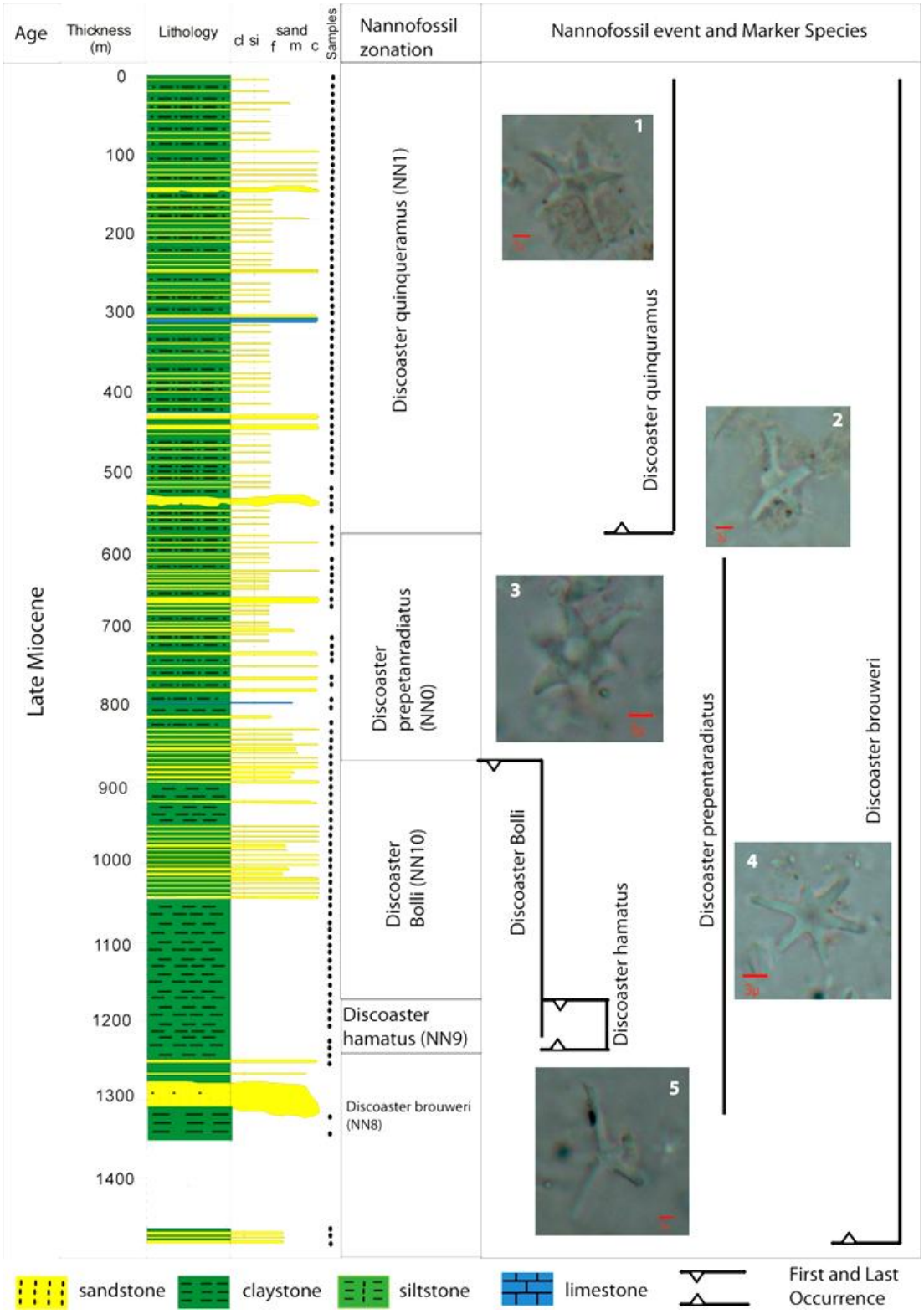


Figure 4*. Nannofossil events and marker species of the Halang Formation in Loh Pasir section: 1. Discoaster quinqueramus; 2. Discoaster prepentaradiatus; 3. Discoaster bolli; 4. Discoaster brouweri;*

The biozonation used in this work (Figure 4) is based on the calcareous nannofossil zonation of Martini (1971) and Okada and Bukry (1980). According to the stratigraphic ranges of calcareous nannofossils in the section, five Late Miocene zones (NN8-NN11) can be identified from the bottom to the upper part of this section.

1. Discoaster brouweri zone (NN8)

We propose *Discoaster brouweri* zone for the lowest part of Kali Pasir section. Martini (1971) identified NN8 as *Catinaster coalithus* zone, but as this species was not found in our location, we used *Discoaster brouweri* to name this basal zone. It is defined from the occurrence of *Discoaster brouweri* to the first occurrence of *Discoster hamatus.* This zone is recorded from the lower part of the Halang Formation with a thickness of about 240m. It is characterized by the following calcareous nannoplankton species: *Calcidiscus leptoporus, Calcidiscus macintyrei, Calcidiscus tropicus, Coccolithus pelagicus, Dictyococcites productus,*

Discoaster bellus, Discoaster brouweri, Discoaster deflandrei, Discoaster exilis, Discoaster intercalaris, Discoaster variabilis, Helicosphaera intermedia, Helicosphaera kamptneri, Helicosphaera orientalis, Pontosphaera discopora, Pontosphaera multipora, Pontosphaera sutellum, Pontosphaera syracussana, Reticulofenestra minuta, Reticulofenestra minutula, Reticulofenestra pseudoumbilica, Sphenolithus abies, Sphenolithus compactus, Sphenolithus grandis, Sphenolithus heteromorphus, Sphenolithus moriformis, Thoracosphaera sp., *Umbilicosphaera jafarii,* and *Umbilicosphaera rotula.*
This zone is assigned to the Late Miocene. In the Banyumas area, it is equivalent to NN8 zone in KRG01 (Lunt et al., 2009). However, the index marker species of *Catinaster coalithus* was found in our location.

2. Discoaster hamatus zone (NN9)
This zone was established by Bramlette and Wilcoxon (1967), emended by Martini (1971). This zone is defined between the first and last occurrences of *Discoaster hamatus*. It was recorded in the Halang Formation at Kali Pasir with a thickness of 80m. The name *Discoaster hamatus* zone (NN9) is in agreement with Martini (1971) and Lunt et al. (2009). This zone ccontains the following calcareous nannofossils: *Calcidiscus leptoporus, Calcidiscus macintyrei, Calcidiscus tropicus, Coccolithus pelagicus, Dictyococcites productus, Discoaster bellus, Discoaster bollii, Discoaster brouweri, Discoaster deflandrei, Discoaster exilis, Discoaster hamatus, Discoaster intercalaris, Discoaster neohamatus, Discoaster surculus, Discoaster variabilis, Helicosphaera intermedia, Helicosphaera granulate, Helicosphaera kamptneri, Helicosphaera orientalis, Pontosphaera discopora, Pontosphaera multipora, Pontosphaera sutellum, Pontosphaera syracussana, Reticulofenestra minuta, Reticulofenestra minutula, Reticulofenestra pseudoumbilica, Sphenolithus abies, Sphenolithus compactus, Sphenolithus grandis, Sphenolithus heteromorphus, Sphenolithus moriformis, Thoracosphaera* sp., *Umbilicosphaera jafarii,* and *Umbilicosphaera rotula*. The age of this zone is Late Miocene. This zone is equal to KRG01 results on NN9 (Lunt et al., 2009).

3. Discoaster bolli zone (lower NN10)
We propose *Discoster bolli* zone as a subzone of the *Discoaster calcaris* zone (NN10), which was originally established by Martini (1969). *Discoaster bolli* zone is used following Okada and Bukry (1980) and this zone is defined by the last occurrence of *Discoaster hamatus* at its base and the last occurrence of *Discoaster bollii* at the top. This zone is 290m thick in the Halang Formation and contains *Calcidiscus leptoporus, Calcidiscus macintyrei, Calcidiscus tropicus, Coccolithus pelagicus, Dictyococcites productus, Discoaster asymmetricus, Discoaster bellus, Discoaster bollii, Discoaster brouweri, Discoaster deflandrei, Discoaster exilis, Discoaster intercalaris, Discoaster neohamatus, Discoaster neorectus, Discoaster pseudovariabilis, Discoaster surculus, Discoaster variabilis, Helicosphaera intermedia, Helicosphaera granulata, Discoaster pentaradiatus, Helicosphaera kamptneri, Helicosphaera orientalis, Helicosphaera stalis, Pontosphaera discopora, Pontosphaera multipora, Pontosphaera sutellum, Pontosphaera syracussana, Reticulofenestra minuta, Reticulofenestra minutula, Reticulofenestra pseudoumbilica, Rhandosphaera procera, Sphenolithus abies, Sphenolithus compactus, Sphenolithus grandis, Sphenolithus heteromorphus, Sphenolithus moriformis, Thoracosphaera* sp., *Umbilicosphaera jafarii,* and *Umbilicosphaera rotula.*
This zone is assigned to the Late Miocene. In the Banyumas area zone NN10 zone was defined by LO of *Discoaster hamatus* and FO of *Discoaster quinqueramus* by Lunt et al. (2009). Within this zone, *Discoaster loeblichi* and *Discoaster neorectus* are used for additional species. However, we prefer to use the marker species *Discoaster bollii,* as established by Okada and Bukry (1980).

4. Discoaster prepentaradiatus zone (upper NN10)
Another subzone within the *Discoaster calcaris* (NN10) zone of Martini (1971) is proposed to apply *Discoaster prepentaradiatus* zone in the Halang Formation succession. This zone is defined by last occurrence of *Discoaster bolli* and the first occurrence of *Discoaster quinqueramus*. The thickness of this zone is 280 m in the Kali Pasir succession. It is characterized by *Calcidiscus leptoporus, Calcidiscus macintyrei, Calcidiscus tropicus, Coccolithus pelagicus, Dictyococcites productus, Discoaster asymmetricus, Discoaster bellus, Discoaster brouweri, Discoaster deflandrei, Discoaster exilis, Discoaster intercalaris, Discoaster neohamatus, Discoaster neorectus, Discoaster surculus, Discoaster variabilis, Helicosphaera intermedia, Helicosphaera granulata, Discoaster pentaradiatus, Discoaster prepentaradiatus, Helicosphaera kamptneri, Helicosphaera orientalis, Helicosphaera stalis, Pontosphaera discopora, Pontosphaera multipora, Pontosphaera sutellum, Pontosphaera syracussana, Reticulofenestra minuta, Reticulofenestra minutula, Reticulofenestra pseudoumbilica, Rhandosphaera procera, Sphenolithus abies, Sphenolithus compactus, Sphenolithus grandis, Sphenolithus heteromorphus, Sphenolithus moriformis, Thoracosphaera* sp., *Umbilicosphaera jafari,* and *Umbilicosphaera rotula.*
The age of this zone is late Miocene. The top of this zone can be used to correlate with the top of first occurrence of *Discoaster quinqueramus* at KRG01 (Lunt et al., 2009). In contrast, the base of this zone is not useful for correlation with KRG01.

5. Discoaster quinqueramus zone (NN11)
This zone was originally established by Gartner (1969c) and emended by Martini (1971). It is defined at the base as the first occurrence of *Discoaster quinqueramus* and the top of this zone is undefined due to lack of marker species of NN11 zone. This zone is 580m thick at the Kali Pasir succession. It is characterized by *Calcidiscus leptoporus, Calcidiscus macintyrei, Calcidiscus tropicus, Coccolithus pelagicus, Dictyococcites productus, Discoaster asymmetricus, Discoaster berggrenii, Discoaster*

bellus, Discoaster brouweri, Discoaster deflandrei, Discoaster exilis, Discoaster intercalaris, Discoaster neohamatus, Discoaster neorectus, Discoaster surculus, Discoaster variabilis, Helicosphaera intermedia, Discoaster pentaradiatus, Helicosphaera kamptneri, Helicosphaera orientalis, Helicosphaera sellii, Helicosphaera wallichii, Pontosphaera discopora, Pontosphaera multipora, Pontosphaera sutellum, Pontosphaera syracussana, Reticulofenestra minuta, Reticulofenestra minutula, Reticulofenestra pseudoumbilica, Rhandosphaera procera, Sphenolithus abies, Sphenolithus compactus, Sphenolithus grandis, Sphenolithus heteromorphus, Sphenolithus moriformis, *Thoracosphaera* sp., *Umbilicosphaera jafarii,* and *Umbilicosphaera rotula.* It is assigned to the Late Miocene, and is equivalent to that of Lunt et al. (2009) In the Banyumas area.

Figure 5 compares our zonation with the zonation proposed by Lunt et al. (2009).

Some selected representative index calcareous nannofossils are illustrated in Figure 4 and Plates 1 and 2. Full names of species cited in the text are given in the captions of Plates 1 and 2.

CONCLUSIONS

We conclude that biostratigraphic zonations in Halang Formation outcrops in the Banyumas area are equivalent to the proposed zonation in the Karang Gedang 1 well core location. Nannofossil datums demonstrate the similar index fossils in the upper part of Halang Formation, i.e. FO *Discoaster quinqueramus,* LO *Discoaster hamatus,* FO *Discoaster hamatus* and an additional proposed datum of FO *Discoaster bolli*. However in the lower part of Halang Formation, we could not find FO *Catinaster coalitus*. We propose the occurrence of *Discoaster brouweri* as a marker for the lower part of Halang Formation.

ACKNOWLEDGEMENTS

We acknowledge the director of the Research Centre for Geotechnology, Indonesian Institute of Sciences, for support during fieldwork of first author for a successful master study at the Institute of Technology Bandung. We are grateful to Mr. Suparyadi and Mr. M. Zulfikri Ramadhan for technical assistance during sampling and sample preparation and we thank Mr. Panuju at the Research and Development Center for Oil and Gas Technology (Lemigas) for helping in calcareous nannofossil descriptions and photographs. We gratefully acknowledge the Institute of Technology Bandung for funding this research in the Banyumas Region.

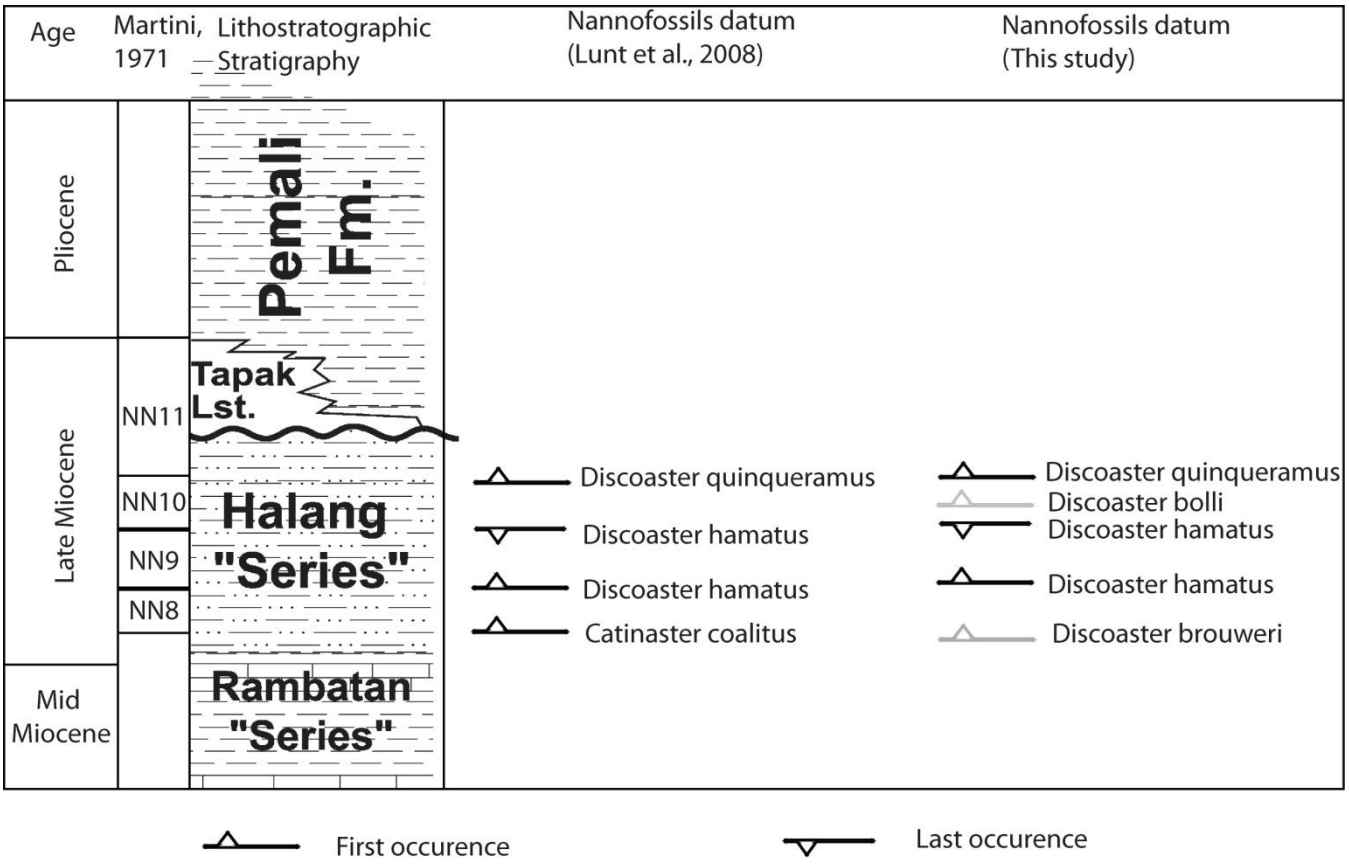


***Figure 5**. Comparison of surface measured-section in Loh Pasir, Banyumas and KRG 01 core from Pertamina Karang Gedang 1 well (Lunt et al., 2009)*

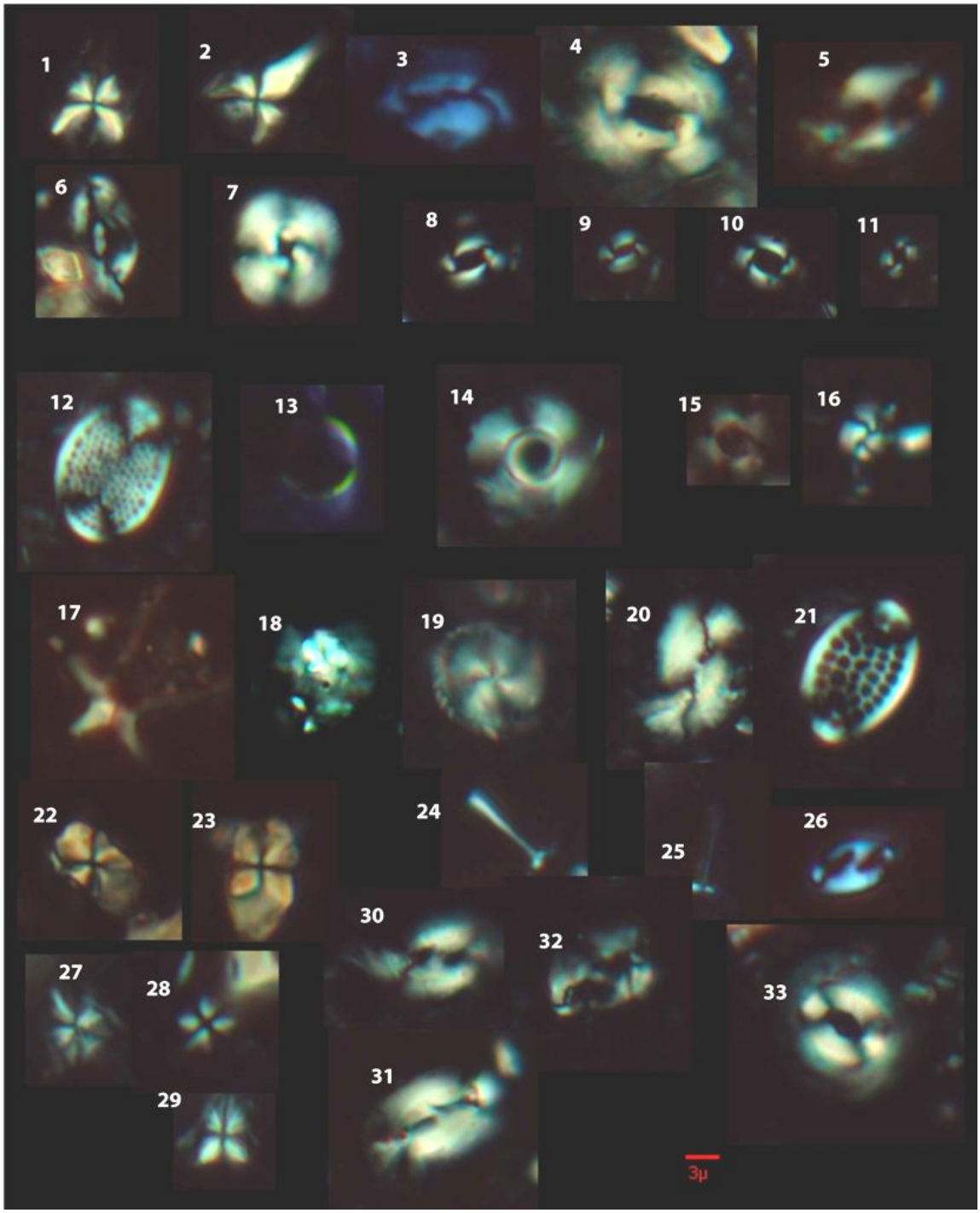


Plate 1- *Representative calcareous nannofossil species: 1. Sphenolithus heteromorphus Deflandre (1953), 2. Sphenolithus heteromorphus* Deflandre (1953), *3. Helicosphaera perch-nielseniae* Haq (1971), *4. Reticulofenestra pseudoumbilica* (Gartner 1967), *5. Helicosphaera walbersdorfensis* Müller (1974b), *6. Helicosphaera intermedia* Martini (1965), *7. Cyclicargolithus floridanus* (Roth and Hay in Hay et al., 1967) Bukry (1971a), *8. Reticulofenestra minutula* (Gartner, 1967) Haq and Berggren (1978), *9. Reticulofenestra minuta* Roth (1970), *10. Reticulofenestra minutula* (Gartner, 1967) Haq and Berggren (1978), *11. Reticulofenestra minuta* Roth (1970), *12. Pontosphaera discopora* Schiller (1925), *13. Umbilicosphaera rotula* (Kamptner, 1956) Varol (1982), *14. Calcidiscus macintyrei* (Bukry and Bramlette, 1969b) Loeblich & Tappan (1978), *15. Umbilicosphaera jafarii* Müller (1974b), *16. Dictyococcittes productus* (Kamptner 1963) Backman (1980), *17. Discoaster pentaradiatus* Tan (1927) emend. Bramlette & Riedel (1954), *18. Calcidiscus tropicus* Kamptner, 1956 sensu Gartner, 1992, *19. Calcidiscus leptoporus* (Murray and Blackman, 1898) Loeblich & Tappan (1978), *20. Helicosphaera kamptneri* Hay & Mohler in Hay et al., (1967), *21. Pontosphaera multipora* (Kamptner 1948) Roth (1970), *22. Sphenolithus moriformis* (Brönnimann and Stradner, 1960) Bramlette & Wilcoxon (1967), *23. Sphenolithus moriformis* (Brönnimann and Stradner, 1960) Bramlette & Wilcoxon (1967), *24. Rhabdosphaera procera* Martini (1969), *25. Rhabdosphaera procera* Martini (1969), *26. Helicosphaera stalis* Theorodilis (1984), *27. Sphenolithus abies* Deflandre, *28. Sphenolithus compactus* Backman (1980), *29. Sphenolithus abies* Deflandre, *30. Helicosphaera sellii* Bukry & Bramlette (1969b), *31. Helicosphaera wallichii* (Lohman, 1902) Boudreaux & Hay (1969), *32.Helicosphaera orientalis* Black (1971a) and*33. Coccolithus pelagicus* (Wallich, 1877) Schiller (1930)

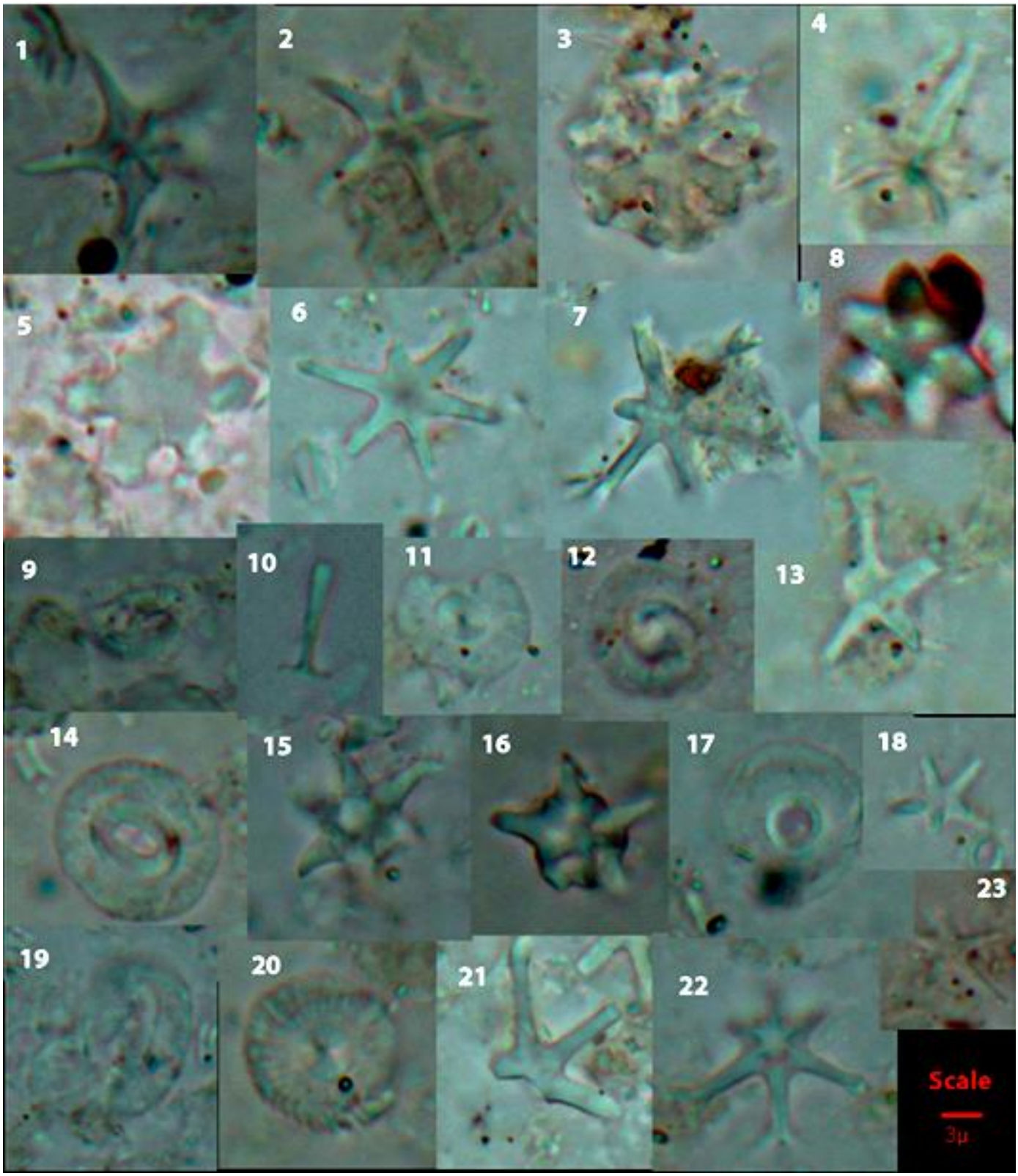


Plate 2-. *Additional representative calcareous nannofossil species: 1. Discoaster berggrenii* Bukry (1971b), *2. Discoaster quinqueramus* Gartner (1969c), *3. Discoaster deflandrei* Bramlette & Riedel (1954), *4. Sphenolithus heteromorphus* Deflandre (1953), *5. Discoaster deflandrei* Bramlette & Riedel (1954), *6. Discoaster brouweri* Tan (1927) emend. Bramlette & Riedel (1954), *7. Discoaster calcaris* Gartner (1967), *8. Discoaster intercalaris* Bukry (1971a), *9. Helicosphaera sellii* Bukry & Bramlette (1969b), *10. Rhabdosphaera procera* Martini (1969), *11. Calcidiscus tropicus* Kamptner, 1956 sensu Gartner, 1992, *12. Cyclicargolithus floridanus* (Roth and Hay in Hay et al., 1967) Bukry (1971a), *13. Discoaster prepentaradiatus* Bukry & Percival (1971), *14. Coccolithus pelagicus* (Wallich, 1877) Schiller (1930), *15. Discoaster bollii* Martini & Bramlette (1963), *16. Discoaster berggrenii* Bukry (1971b), *17. Calcidiscus macintyrei* (Bukry and Bramlette, 1969b) Loeblich & Tappan (1978), *18. Discoaster bellus* Bukry & Percival (1971), *19. Helicosphaera kamptneri* Hay & Mohler in Hay et al., (1967), *20. Calcidiscus leptoporus* (Murray and Blackman, 1898) Loeblich & Tappan (1978), *21. Discoaster neohamatus* Bukry & Bramlette (1969b), *22. Discoaster variabilis* Martini & Bramlette (1963), *23. Discoaster asymmetricus* Gartner (1969c).

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