Planktonic foraminifera biozonation of the Middle Eocene-Oligocene Kebo Formation, Kalinampu area, Bayat, Klaten, Central Java

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ABSTRACT

Research on foraminifera from the Paleogene volcanoclastics-dominated Kebo Butak Formation of Central Java is limited. A study was conducted in the Kalinampu and surrounding areas of Bayat, Klaten, Central Java. The study included measuring of three stratigraphic sections and geological mapping. The study area contains the Nampurejo pillow lava, which is considered to be the base of the Kebo-Butak Formation (part of the 'Old Andesites' complex of South Java), but its Middle Eocene age is older than previously assumed.

Correlation and biozone interpretation allowed the recognition of 12 planktonic foraminifera zones, ranging in age from Middle Eocene (P11) to Early Miocene (N5). Depositional environments are all deep marine, ranging from lower bathyal to upper bathyal.

INTRODUCTION

The purpose of this study was to determine the Eocene-Oligocene planktonic foraminifera biozonation and age of the lower part of Kebo Formation in the Kalinampu, Sendangrejo and Mojosari areas, Bayat district, Klaten, approximately 40 kilometers SE of the city of Yogyakarta (Figure 1). The Kebo formation is dominated by volcanoclastic sediments, deposited in a marine environment, and is important because it demonstrates a period of early volcanism in the Southern Mountains of Java. The thick volcanoclastic-rich section is underlain by a relatively thin series with white marls that are rich in Middle Eocene - Early Oligocene deep marine planktonics-dominated faunas, and which are the focus of this study.

The post-Kebo-Butak Miocene planktonic foraminifera biozonation in the Southern Mountains of Central Java was well documented by Kadar (1986), but research on Paleogene foraminifera near the base of the Kebo Formation has been very limited. Sumarso and Ismoyowati (1975) were the first to mention the presence of Middle and Late Eocene (P14-P15) planktonic foraminifera in the Wungkal-Gamping Formation of the nearby Jiwo hills, but they did not provide any details on faunal succession and localities. The other area in Central Java from which similar Eocene planktonic foraminifera have been reported is the Nanggulan area, West of Yogyakarta (Hartono 1969; Siregar and Harsono 1981 and an unpublished study by Lunt and Sugiatno, 2003).

This paper reports the results of our study on small foraminifera in the Kalinampu, Sendangrejo, Mojosari and Mranggen areas (Figure 1). The outcrop sections selected in the area are considered to represent the basal part of the Kebo Formation, because they are located closest to the Nampurejo pillow lava, which is considered to be the base of the formation. While there are some complexities such as faults, it is still relatively easy to reconstruct a continuous rock sequence.

REGIONAL GEOLOGY AND STRATIGRAPHY

The study area is part of the Southern Mountains of Central Java, at the northern margin of what Van Bemmelen (1949) called the Baturagung Range. According to Toha et al (1994) the Cenozoic sediments of the Southern Mountains were mainly formed by gravity depositional processes, and are about 4000 meters thick. Almost the entire section is tilted to the south due to tectonic forces active since the Late Oligocene to Late Miocene.

Basement of the basin is composed of pre-Tertiary metamorphic rocks. According to Sumosusastro (1956) these rocks are composed of phyllite, mica schist, gneiss and crystalline limestones. Metamorphic basement is overlain by the Eocene Wungkal-Gamping Formation, which is composed of Eocene sandstone, sandy marl, mudstone, claystone and limestone lenses. Overlying the Wungkal-Gamping Formation are the Kebo-Butak, Semilir and Nglanggran Formations, all are composed of volcanoclastic sediments. They represent a period of intensive volcanic activity in

the Southern Mountains, and were referred to as 'Old Andesites' by Van Bemmelen (1949).

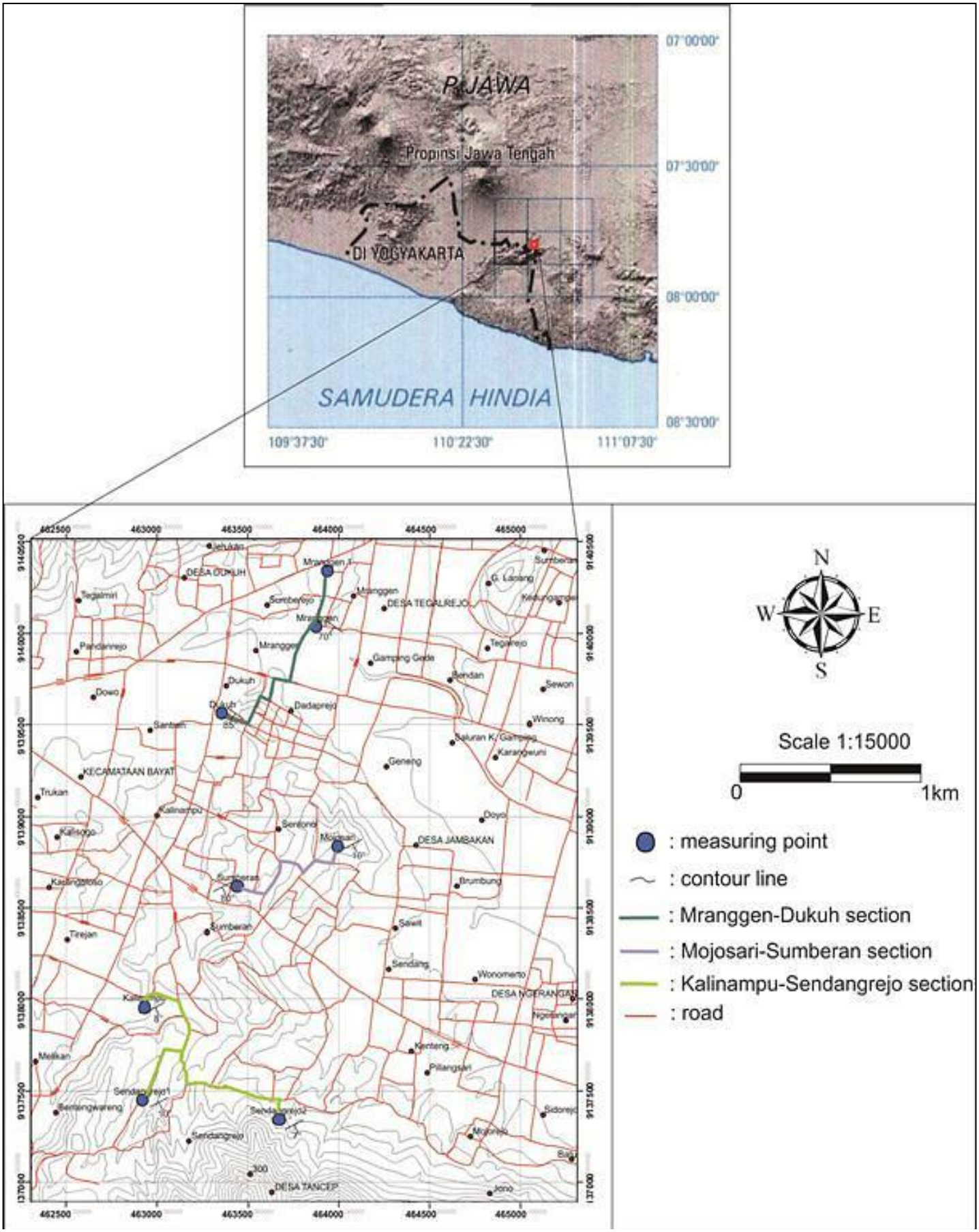


Figure 1. *Location map of study area SE of Yogyakarta, showing three lines of measured sections.*

Our study is focused mainly on the lower part of Kebo Formation. A comparison of Southern Mountains stratigraphic columns from several researchers shows that different authors assigned different ages to the Kebo Formation (Figure 2). Toha et al. (1994) and Surono (2009) placed the age of the base of the Kebo-Butak Formation in the Early Oligocene (N2).

The Kebo-Butak Formation was deposited in a marine basin surrounded by active volcanoes. The volcanoes became major sediment suppliers to the nearby basin. The oldest volcanic deposit is the Nampurejo pillow lava (Figure 4). According to Surono (2008) the age of the Nampurejo pillow lava is between ~33.2 to 31.3 Ma (Early Oligocene), older than the age of most of the volcanoclastic Kebo-Butak Formation, which generally ranges between ~26.5 and 21 Ma (Late Oligocene - Early Miocene). Deposition of the Kebo-Butak formation indicated widespread arc volcanism in the Southern Mountains.

Geology of the Kalinampu Area

Geological mapping was conducted to determine the lateral distribution of the rocks. The oldest fossiliferous rock is the mudrock micrite layer that is intercalated between volcanic breccias (Figure 3) . The age of the layer is P11 (Middle Eocene). This facies is thinning to the northwest. The source of sediment was derived from the southeast entrance into the basin, and then spread towards the northwest. Above this facies primary volcanic products were deposited, such as lava and pyroclastic rocks. In some places pillow lava structures are found (Figure 4). In the East of the area of research a polymict breccia lithology is developed with tuff fragments, clay and sand, probably in a tuff matrix.

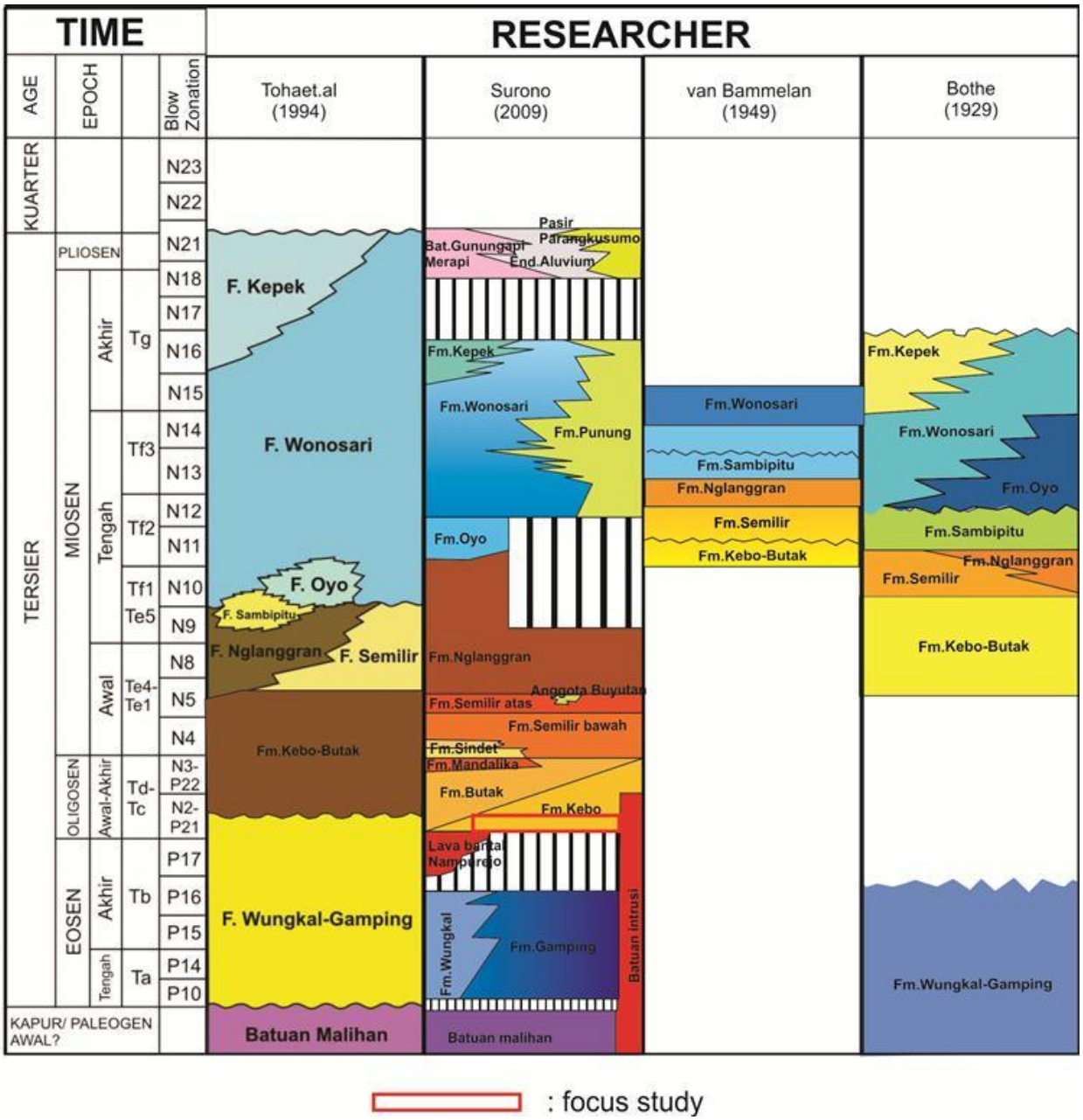


Figure 2. *Compilation of Southern Mountains regional stratigraphy from previous authors. Focus for this study is the lower part of the Kebo Formation, here concluded to range from P14 - N5 (Middle Eocene - Early Miocene).*

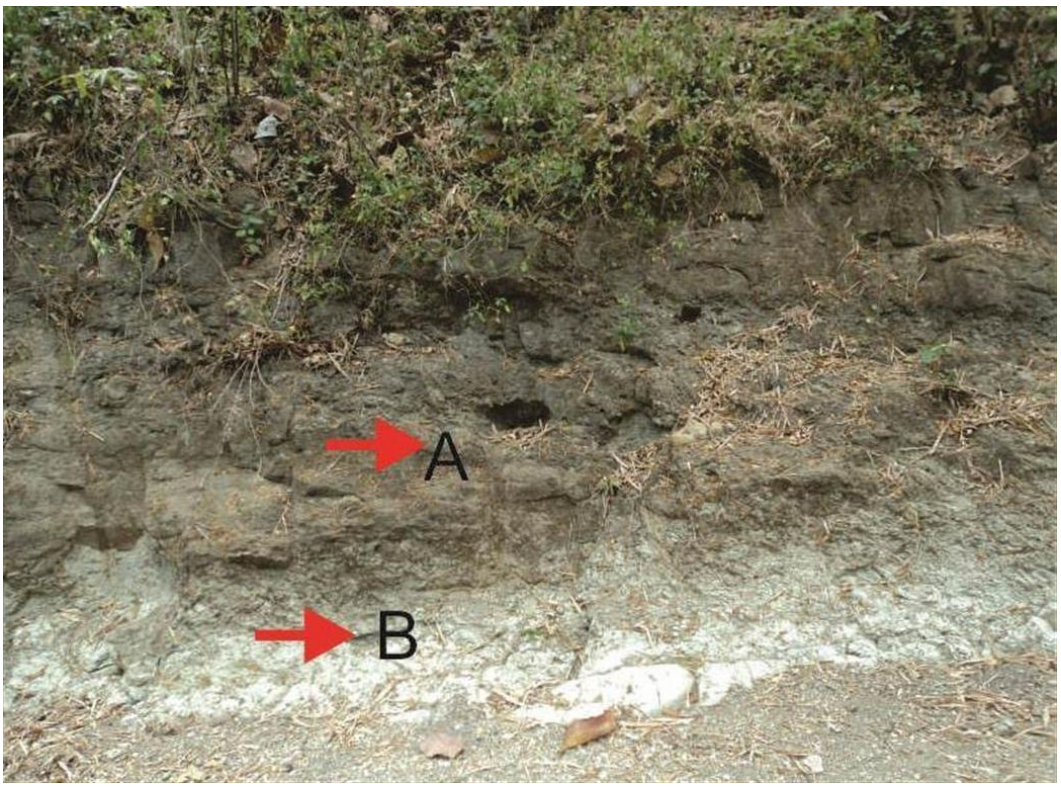


Figure 3. *Outcrop of dark volcanic breccia (A) underlain by white micrite mudrock facies (B).*

Figure 4. *Outcrop of Nampurejo Lava with pillow structures (A).*

Significant geological structures developed in the study area, with several major faults. The Kalinampu-Mojosari fault is a strike slip with a vertical component. The fault plane was observed in the Kalinampu river cliffs, where the fault plane parallels the direction of the river. Strike and dip of the Kalinampu fault plane are N70°E/77° or trending NE-SW. The lineament is terminated by another NW-SE trending lineament. Other faults include the Mojosari reverse fault and the Sumberan normal fault. The distribution of formations and faults in the study area is shown on the geological map of Figure 5.

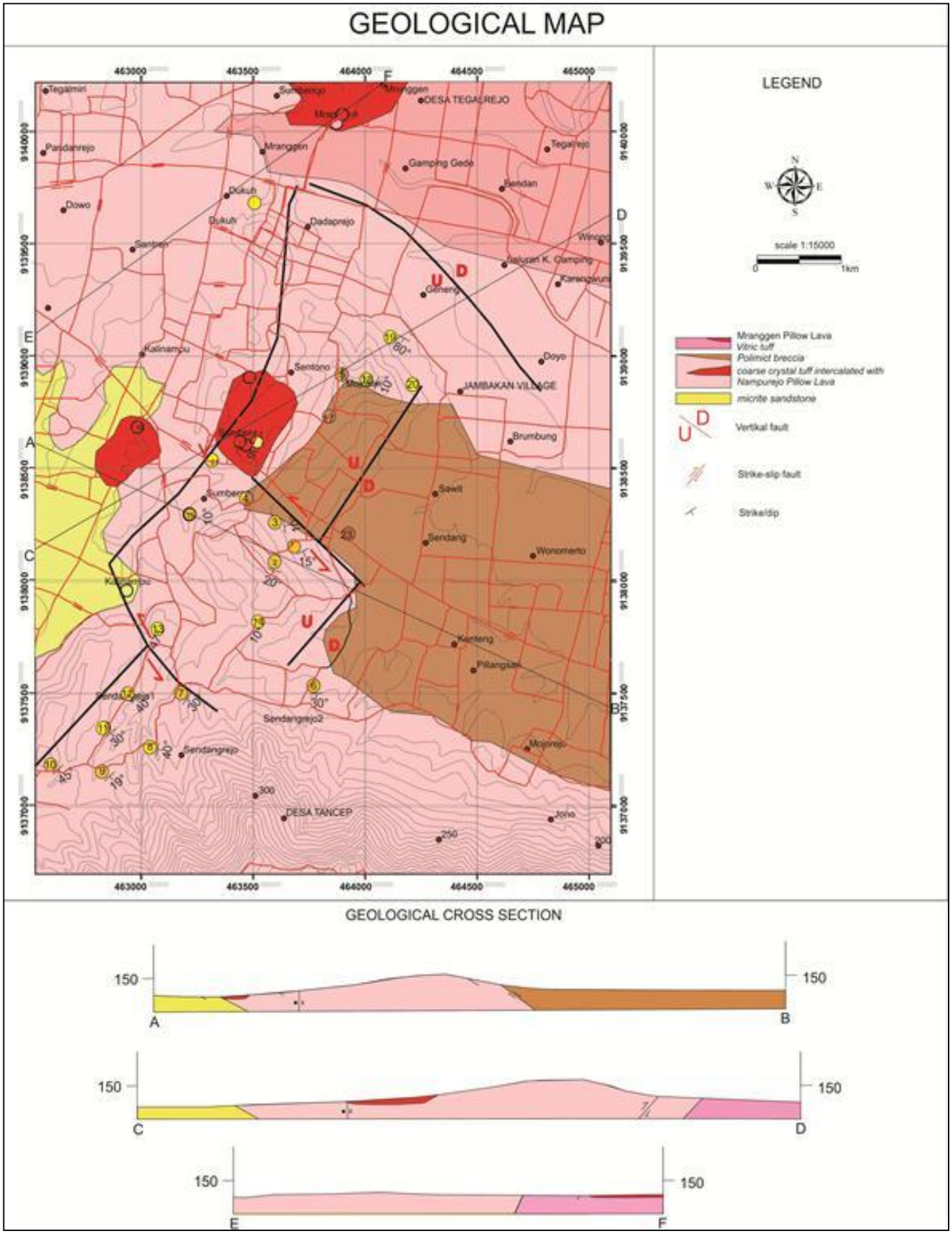


Figure 5. *Geological map of study area.*

METHODOLOGY

Three stratigraphic sections were measured in the study area to determine the stratigraphic succession of rocks in the field (Appendices 1-3). The measurement technique included the use of a Jacob stick, so there is no need for thickness corrections. Paleontological samples were taken from layers of fine-grained rocks and some of the coarser-grained rocks, and then sieved to obtain the small foraminifera fossils. The standard sampling interval for paleontology was 1 meter. However, because the foraminifera were most abundant in the lower part of the section, paleontological sampling was maximized at the base of the measured section. Petrographic samples were taken to represent each of the facies in study area.

BIOZONATION RESULTS

From the study of the distribution of foraminifera in each measured section, followed by correlations, we identified 12 zones of planktonic foraminifera as defined by Bolli et al. (1985) in the Kalinampu-Sendangrejo section (Appendix 1), 7 zones in the Sumberan-Mojosari section (Appendix 2) and one zone in the Mranggen-Dukuh section (Appendix 3). The composite section in the study area contains 12 zones:

Zone 1 (Middle Eocene Zone-P11)
This zone is only found in the Kalinampu-Senangrejo section. The lower limit of this zone is unknown while the upper boundary of this zone is characterized by the appearance of *Globigerinatheka subconglobata curryi*. Planktonic foraminifera species found in this zone include *Globigerinatheka mexicana, Globigerinatheka index, Globigerinatheka subconglobata, Planorotalites pseudoscitula, Pseudohastigerina danvillensis, Truncorotaloides rohri* and *Turborotalia cerroazulensis*.

Zone 2 (Middle Eocene Zone-P12)
This zone is found only in the Kalinampu-Sendangrejo section and is marked by *Morozovella lehneri* range zone, characterized by the presence of *Morozovella lehneri*. Other fossils in this zone include *Acarinina spinuloinflata, Globigerina eocaena, Globigerinatheka mexicana kugleri, Globorotaloides carcoselleensis, Hastigerina cf. bolivariana, T. cerroazulensis possagnoensis - pomeroli* transition, *T. cerroazulensis* and *T. cerroazulensis pomeroli*.

Zone 3 (Middle Eocene Zone-P13)
This zone is found only in the Kalinampu-Sendangrejo section. The base of the zone is defined by the last occurrence of *Globigerinatheka kugleri mexicana* and the top by the last occurrence of *Globigerinatheka subconglobata*. Other fossils found in this zone includes *Acarinina spinuloinflata, Catapsydrax dissimillis, Globigerina eocaena, G. medizzani, Globigerinatheka subconglobata luterbacheri, Globorotaloides possagnoensis, Planorotalites pseudoscitula, Pseudohastigerina danvillensis, Turborotalia cerroazulensis possagnoensis pomeroli* transition, *Truncatulinoides rohri, Turborotalia centralis* and *T. cerroazulensis pomeroli*.

Zone 4 (Middle Eocene Zone-P14)
This zone is found in the Kalinampu-Sendangrejo and Sumberan-Mojosari sections. In the Kalinampu-Sendangrejo section, the base of the zone is marked by the first occurrence of *Globigerina medizzani*, the top by the last occurrence of *Planorotalites pseudoscitula*. Other foraminifera in this zone include *Acarinina rugosoaculatea, A. spinuloinflata, Catapsydrax dissimillis, Globigerina cryptomphala, G. eocaena, G. senni, G. mexicana, Globoborotaloides carcoselleensis, Pseudohastigerina danvilensis, T. cerroazulensis possagnoensis - pomeroli* transition, *Turborotalia cerroazulensis pomeroli* and *Truncorotaloides rohri*. In the Sumberan-Mojosari section, zone P14 is marked by a partial *Globorotaloides carcoseleensis* zone. The lower part at this zone is unknown and the upper initiated by the first occurrence of *Globorotaloides carcoseleensis*. Foraminifera in this zone include *Catapsydrax dissimilis, Globigerinatheka subconglobata luterbacheri* and *Turborotalia cerroazulensis pomeroli*.

Zone 5 (Late Eocene Zone-P15/16)
This zone was found in two sections. In the Kalinampu-Sendangrejo section the base of the zone is marked by the last occurrence of *Globigerina sennii*, the top by the first occurrence of *Globigerinatheka mexicana*. Other fossils found in this zone include *Acarinina spinuloinflata, Globigerina cryptomphala, G. medizzani, Globigerinatheka index tropicalis, Globorotaloides carcoselleensis, Pseudohastigerina danvillensis, Turborotalia cerroazulensis possagnoensis - pomeroli* transition and *T. cerroazulensis pomeroli*. In the Sumberan- Mojosari section, this zone is bound by the first occurrence of *Globigerinatheka subconglobata luterbacheri* and ends with the first occurrence of *Globigerina praeturrilina*. Other species in this zone are *Catapsydrax dissimilis, Globigerina ampliapertura, G. cryptomphala, G. eupertura, G. hagni, G. lozanoi, G. praebulloides occlusa, G. praeturrilina, G. tripartita* and *Turborotalia cerroazulensis pomeroli*. Reworked fossils from erosion of older rocks include *Globigerina corpulenta, G. sennii* and *Turborotalia griffinae*.

Zone 6 (Late Eocene Zone-P16/17)
This zone is found in two sections. In the Kalinampu-Sendangrejo section, the base of this zone is defined by the last occurrence of *T. cerroazulensis possagnoensis - T. pomeroli* transition, while the top is marked by the first occurrence of *Globigerina yeguaensis*.

Other fossils are *Globigerina eocaena, G. hagni* and *G. pseudovenezuelana*. The most abundant species is *T. cerroazulensis pomeroli*. In the Sumberan-Mojosari section, the base of the zone is the first occurrence of *Globigerina tripartita* and it ends with the first occurrence of *Turborotalia cerroazulensis cunialensis*. Other species present are *Catapsydrax dissimilis, Globigerina ampliapertura, G. praebulloides leroyi, G. sellii* and *G. subconglobata luterbacheri*.

Zone 7 (Early Oligocene Zone-P18/19)
This zone is also found in two sections. In Kalinampu-Sendangrejo, the base of this zone is marked by the first occurrence of *Globigerina yeguensis* and the top by the first occurrence of *Globorotalia opima nana*. Other fossils in this zone are *Catapsydrax dissimillis, Globigerina eupertura, G. ampliapertura, G. ciperoensis angulioficinalis, G. cryptomphala, G. eocaena, G. ouachitaensis, G. praebulloides* and *G. praebulloides leroyi*. The most abundant foram species is *Globigerina yeguensis*. In the Sumberan-Mojosari section, this zone is defined by the last occurrence of *Globigerina sellii* at the base and the last occurrence of *Globigerina tapurensis* at the top. Other species in this zone are *Catapsydrax dissimilis, Globigerina ampliapertura, T. cerroazulensis pomeroli - cerroazulensis* transition and *Turborotalia centralis*. Reworked fossils include *Globigerina hagni* and *G. subconglobata*. The *Globigerina ampliapertura* partial range zone is similar to P19. This zone is unknown for the lower boundary and the top is marked by the last occurrence of *Globigerina ampliapertura*. Many fossils were found reworked: *Globigerina hagni, Turborotalia cerroazulensis cocoaensis, Globigerina lozanoi, Globorotaloides carcoselleensis, Hankenina alabamensis* and *Turborotalia centralis*.

Zone 8 (Middle Oligocene Zone-P20/N1)
In the Kalinampu-Sendangrejo section, the lower part of this zone is marked by the first occurrence of *Globigerina ampliapertura*, the upper part by the first occurrence of *Globorotalia venezuelana*. Other fossils found in this zone are *Globigerina yeguensis* and *Globorotalia opima nana*. The most abundant species is *Globigerina ampliapertura*. In the Sumberan-Mojosari section, this zone is between the last occurrence of *Globigerina ampliapertura* at the base and the first occurrence of *Globigerina yeguensis* at the top. Other species in this zone are *Catapsydrax dissimilis, Globigerina ciperoensis angulioficinalis, G. praebulloides leroyi* and *Globorotalia opima nana*. Reworked Eocene fossils include *Globigerapsis index, Globigerina pseudovenezuelana, Globorotalia ehrenbergi, Orbulinoides beckmanni* and *Planorotalites pseudoscitula*.

Zone 9 (Middle Oligocene Zone-P21/N2)
In the Kalinampu-Sendangrejo section, this zone is characterized by the range of *Globorotalia opima opima*. Other foraminifera in this zone are *Globigerina ampliapertura, G. tripartita, G. venezuelana* and *G. yeguensis*. In the Sumberan-Mojosari section, this zone is also characterized by the *Globorotalia opima nana* range zone. Other species present are *Globigerina praebulloides occlusa* and *G. tripartita*. There are many reworked Eocene species: *Globigerina medizzani, Globigerina praeturrilina, Globigerina sennii, Globorotaloides carcoselleensis, Hastigerina bolivariana, Morozovella lehneri, Planorotalites pseudoscitula* and *P. renzi*.

Zone 10 (Late Oligocene Zone-N3)
The base of this zone is the last occurrence of *Globorotalia opima opima* and the top is the first occurrence of *Globigerina ciperoensis angulisuturalis*. Other fossils found in this zone are *Catapsydrax dissimilis, Globigerina praebulloides leroyi, G. praebulloides occlusa, Globigerinoides primordius, Globorotalia mayeri* and *Globorotalia opima opima* transition to *nana*. The dominant species is *Globigerina angulisuturalis*. In the Sumberan-Mojosari section, this zone was not found, but on the track Mranggen-Hamlet sample DKH12 contained *Globigerina binaiensis*, *Globigerina opima nana-opima* transition and *Globorotalia mayeri* and *Globigerina tripartita*. This suggests most this section is within the zone N3 age range.

Zone 11 (Early Miocene Zone-N4)
This zone is only found in the Kalinampu-Sendangrejo section and is marked by the range of *Globigerinoides primordius*. Other fossils found in this zone are *Catapsydrax dissimilis, Globigerina binaiensis, G. angulisuturalis, G. ciperoensis, G. praebulloides leroyi, G. praebulloides occlusa, G. pseudovenezuelana, G. tripartita, G. venezuelana, G. yeguensis* and *Globorotalia opima nana - opima opima* transition.

Zone 12 (Early Miocene Zone-N5)
This zone is found only in the Kalinampu-Sendangrejo section and is between the first occurrence of *Globigerina binaiensis* at the base and the last occurrence of *Globigerina venezuelana* at the top. In the zonation of Blow (1969) this corresponds to zone N5. Other fossils in this zone are *Globigerina praebulloides leroyi, G. praebulloides occlusa, G. sellii, G. tripartita, G. venezuelana, G. yeguensis* and the *Globorotalia opima opima - G. opima nana* transition.

DEPOSITIONAL ENVIRONMENTS

Interpretations of depositional environments were made by using small benthic foraminifera. Depositional environments of the Eocene - Early Miocene in this region are all deep, open marine and range from lower bathyal to upper bathyal. The Kalinampu-Sendangrejo section located in the southern study area is in the areas of deepest marine facies, as shown by the benthic foraminifera *Bolivina robusta, Cibicides robertsonianus, Globulina minuta,*

Gyroidina broekhiana, Gyroidinoides soldanii, Lenticulina edinata, Neoponides magnitifer, Nodogenerina virgule, Nodosaria flintii, Oridorsalis umbonata, Pseudoglandulina comatula, Uvigerina auberiana and *Uvigerina schwageri*. This foraminifera association suggests sedimentation in top of the lower bathyal zone.

The Sumberan-Mojosari section, located NE of the Kalinampu-Sendangrejo section, shows a shallower paleoenvironment than the Kalinampu-Sendangrejo section. Benthic foraminifera identified include *Amphicoryna* sp., *Neoponides margaritifer*, *Planularia siddalliana* and *Praemassillina arenaria*. This foraminiferal association suggests the sediments were deposited near the top of the upper bathyal zone. The Late Oligocene in the Mranggen-Dukuh section in the northern part of the study area is the shallowest. The presence of the benthic foram species *Globulina inaequalis* suggests the depositional environment is outer neritic.

DISCUSSION

The presence of Eocene planktonic foraminifera from the basal Kebo Formation in this part of the Southern Mountains has not been documented before, although many of the species mentioned in Sumarso and Ismoyowati (1975) from the Wungkal-Gamping Formation of the Jiwo Hills and by Siregar and Harsono (1981) and Lunt and Sugiatno (2003) from the Nanggulan area are also found in our study area.

The contact between the Eocene pillow lavas with sedimentary rocks can clearly be seen in the Sumberan-Mojosari section, where sediments above the pillow lava at Sumberan are correlated with zone P14 (Middle Eocene), based on the presence of *Truncorotaloides rohri*. The Nampurejo-Kalinampu pillow lava is located in the village and does not have clear boundaries with sediments sampled in the Kalinampu-Sendangrejo section. It is assumed to be the same as the Sumberan pillow lava which is older than P14. The separation of the pillow lava outcrops between Nampurejo and Sumberan is assumed to be due to lateral shift by the major shear fault in the area (Figure 5).

Surono (2009) mentioned that the Nampurejo pillow lava is the base of the volcanoclastic Kebo-Butak Formation sediments. From the biozonation data obtained above, the Sumberan and Nampurejo pillow lavas are older than zones Middle Eocene zones P12-P14. In the Kalinampu-Sendangrejo section, we found sediments below the pillow lava that indicate Middle Eocene planktonic foram zone P11 (*Globigerinatheka subconglobata curryi* zone). It is possible that the Nampurejo pillow lava should not be viewed as the base of the Kebo Formation sediments. The lava flow may only represent one or more relatively limited episode(s) of submarine basaltic volcanism in a time characterized mainly by continuous Middle Eocene- Early Oligocene deep marine pelagic sedimentation, and not necessarily the onset of voluminous arc volcanics that characterize the younger, Late Oligocene-earliest Miocene part of the Kebo-Butak, Semilir and Nglanggran sections. An alternative lithostratigraphic interpretation is to view the Middle Eocene-Early Oligocene section in the study area as the deep water equivalent of the Wungkal-Gamping Beds of earlier authors (Figure 2). However, we do suggest that starting from zone P12 (Middle Eocene; with the presence of *Morozovella lehneri*, Figure 6.3) the stratigraphy in this area of the Southern Mountains of Central Java is dominated by volcanic material.

CONCLUSION

Biozonation analyses of planktonic and small benthic foraminifera in three measured sections show that sediments in the study area were deposited since zone P11 (Middle Eocene). It demonstrates that the Middle-Late Eocene in this part of the Southern Mountains of Central Java was deposited in a deep, open marine facies, deeper than age-equivalent sediments in the Nanggulan area further west.

Starting from zone P12 sediments are dominated by volcanics, although the peak of volcanism, with the highest sedimentation rates, appears to be around zone N3 (Late Oligocene). This proves that volcanism in the Southern Mountains of Central Java started much earlier than previously suspected.

Appendix 1. *Middle Eocene-Early Miocene biozonation of the Kalinampu-Sendangrejo section. This is the most complete of the three section studied. Total thickness is 390m, half of which is interpreted as Zone N3 (Late Oligocene; Kebo-Butak volcanoclastics). Thickness of the Eocene basal part of the section (P11-P17) is 60m.*

Appendix 2. *Late Eocene-Oligocene biozonation of the Sumberan-Mojosari Section. Total thickness 285m. Base of section is the Sumberan pillow lava, which is overlain by marl of Middle Eocene (zone P14) age. Most of the Middle Eocene- Early Oligocene section is composed of volcanoclastics.*

Appendix 3. *Late Oligocene biozonation of the Mranggen-Dukuh section. Total thickness 183m, entirely composed of thick volcanoclastic fining-upward beds. Most samples from mudstone interbeds are barren, except for Late Oligocene (zone N3) planktonic foraminifera near top.*

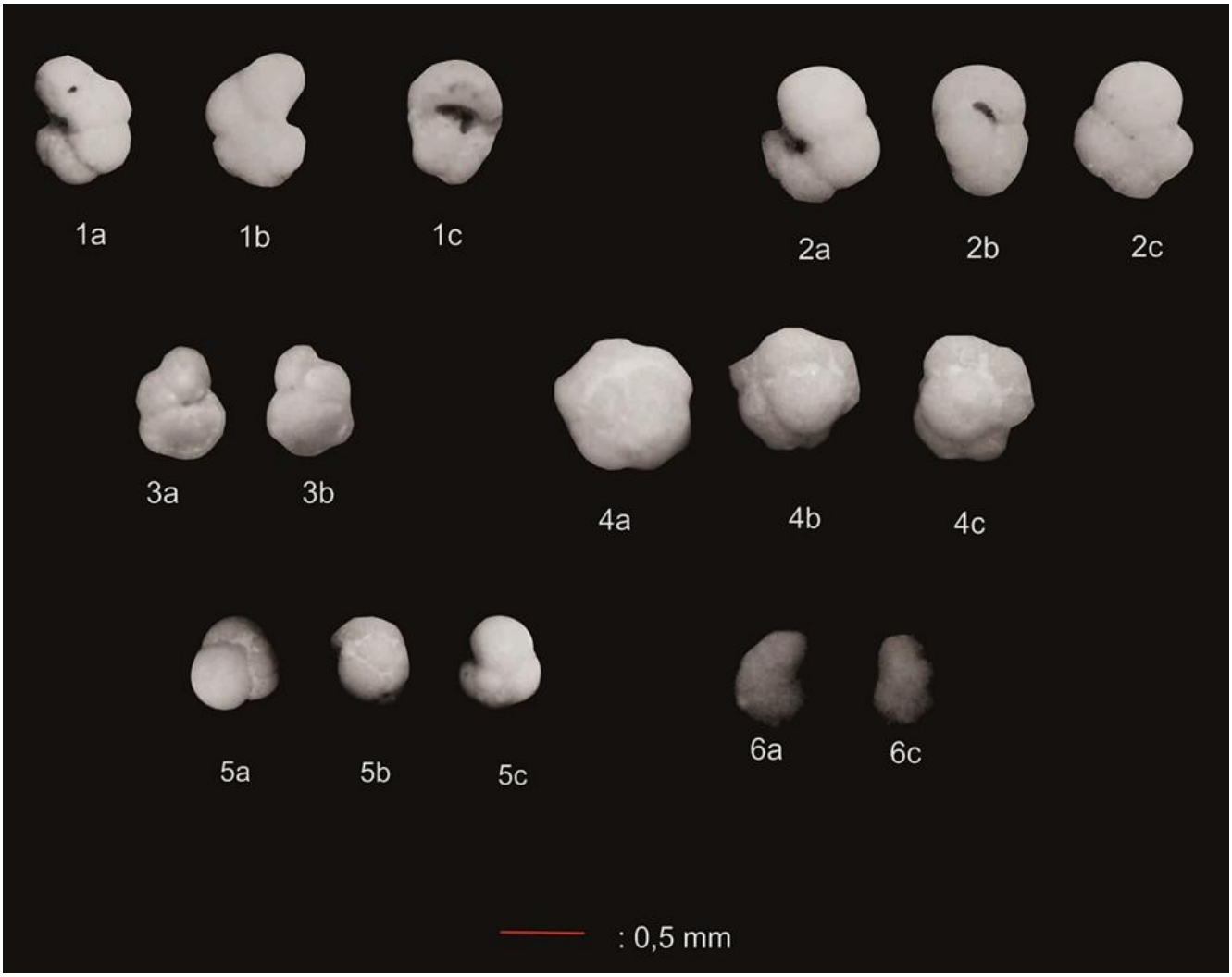


Figure 6. *Eocene planktonic foraminifera from the Kalinampu area. 1.* Truncorotaloides rohri, 2. Turborotalia cerroazulensis pomeroli, 3. Morozovella lehneri, 4. Globigerinatheka subconglobata curryi, 5. Globigerinatheka cryptomphala, 6. Turborotalia cerroazulensis cunialensis.

REFERENCES

Blow, W.H., 1969. Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy. Proc. First Int. Conf. Planktonic Microfossils, Geneva 1967, 1, Brill, Leiden, p. 199-422.

Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K., 1985. Plankton Stratigraphy. Cambridge University Press, London, 1032p.

Bothe, A.C.D., 1929. The geology of the Hills near Djiwo and the Southern Range. 4th Pacific Science Congress, Bandung, 23 p.

Hartono, H.M.S., 1969. *Globigerina* marls and their planktonic foraminifera from the Eocene of Nanggulan, Central Java. Contr. Cushman Found. Foram. Res. 20, 4, p. 152-159.

Kadar, D., 1986. Neogene planktonic foraminiferal biostratigraphy of the South Central Java area, Indonesia. Geol. Res. Dev. Centre, Bandung, Spec. Publ. 5, p. 1-83.

Lunt, P. and Sugiatno, H., 2003. A review of the Eocene and Oligocene in the Nanggulan area, South Central Java, 34p. *(Unpublished Report)*

Siregar, P. and Harsono P., 1981. Stratigraphy and planktonic foraminifera of the Eocene-Oligocene Nanggulan Formation, Central Java. Publ. Geol. Res. Dev. Centre, Bandung, Paleont. Ser. 1, p. 9-28.

Sumarso and Ismoyowati, T., 1975. Contribution to the stratigraphy of the Djiwo Hills and their southern surroundings (Central Java). Proc. 4th Ann. Conv. Indon. Petrol. Assoc. (IPA) p. 19-26, Jakarta.

Sumosusastro, S., 1956. A contribution to the stratigraphy of Eastern Djiwo Hill and the Southern Range in Central Java. Indonesian Journal of Natural Science 112, 115-134.

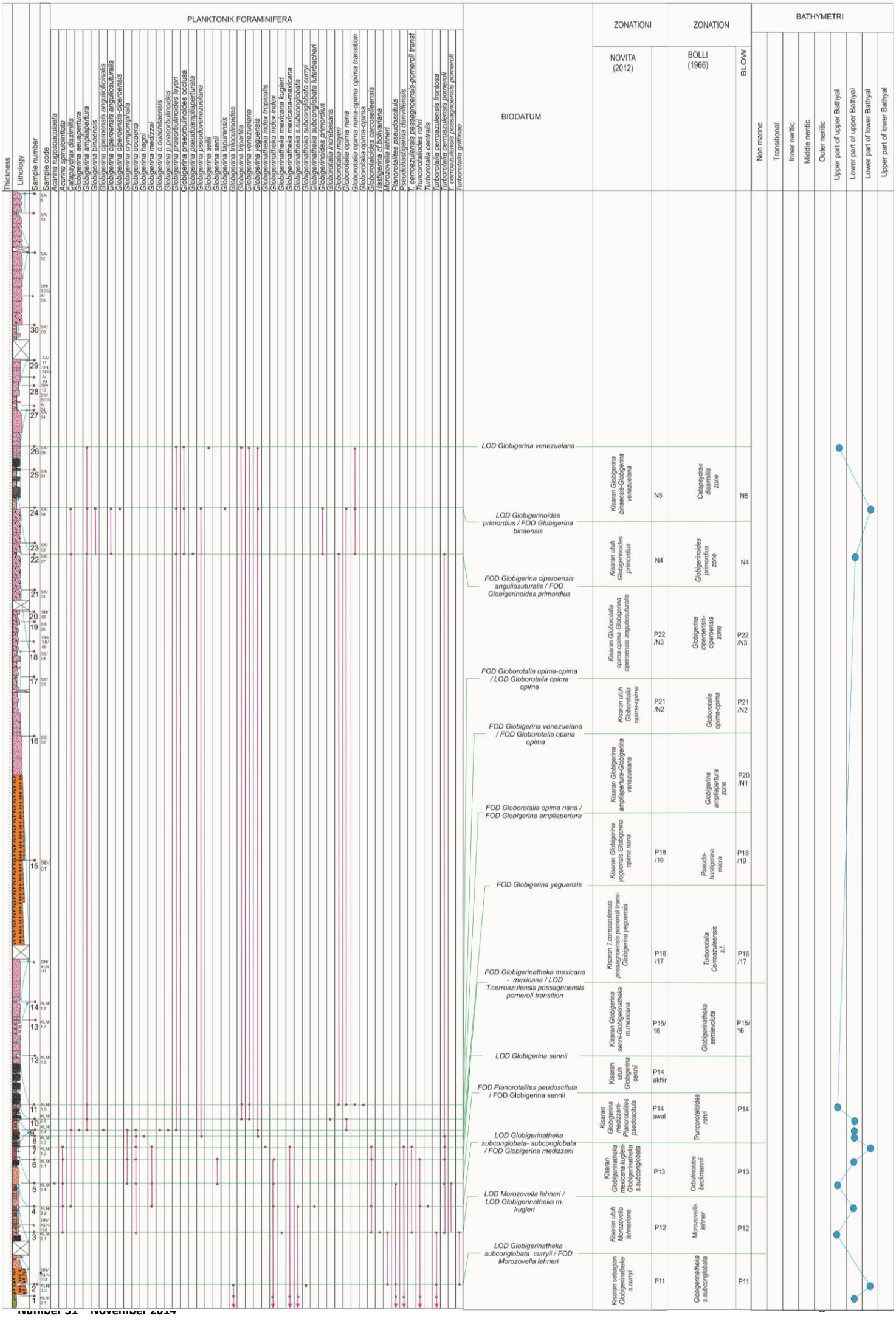
Surono, 2008. Litostratigrafi dan sedimentasi Formasi Kebo dan Formasi Butak di Pegunungan Baturagung, Jawa Tengah Bagian Selatan**.** Jurnal Geologi Indonesia 3, 4, p. 183-193.

Surono, 2009. Litostratigrafi Pegunungan Selatan bagian Timur Daerah Istimewa Yogyakarta dan Jawa Tengah. Jurnal Sumber Daya Geol. 19, 3, p. 209-221.

Toha. B., Purtyasti, R.D., Sriyono, Soetoto, Wartono R., Subagyo P., 1994. Geologi daerah Pegunungan Selatan, Suatu Kontribusi, Fakultas Teknik, Universitas Gadjah Mada.

Van Bemmelen, R.W., 1949. The Geology of Indonesia, Vol. 1 A, Government Printing Office, Nijhoff, The Hague, 732p.

APPENDIX 1


PLANKTONIK FORAMINIFERA
Acarinina rugosoaculeata
Acarinina spinuloinflata
Catapsydrax dissimilis
Globigerina aeuapertura
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Globigerina binaensis
Globigerina ciperoensis angulisuturalis
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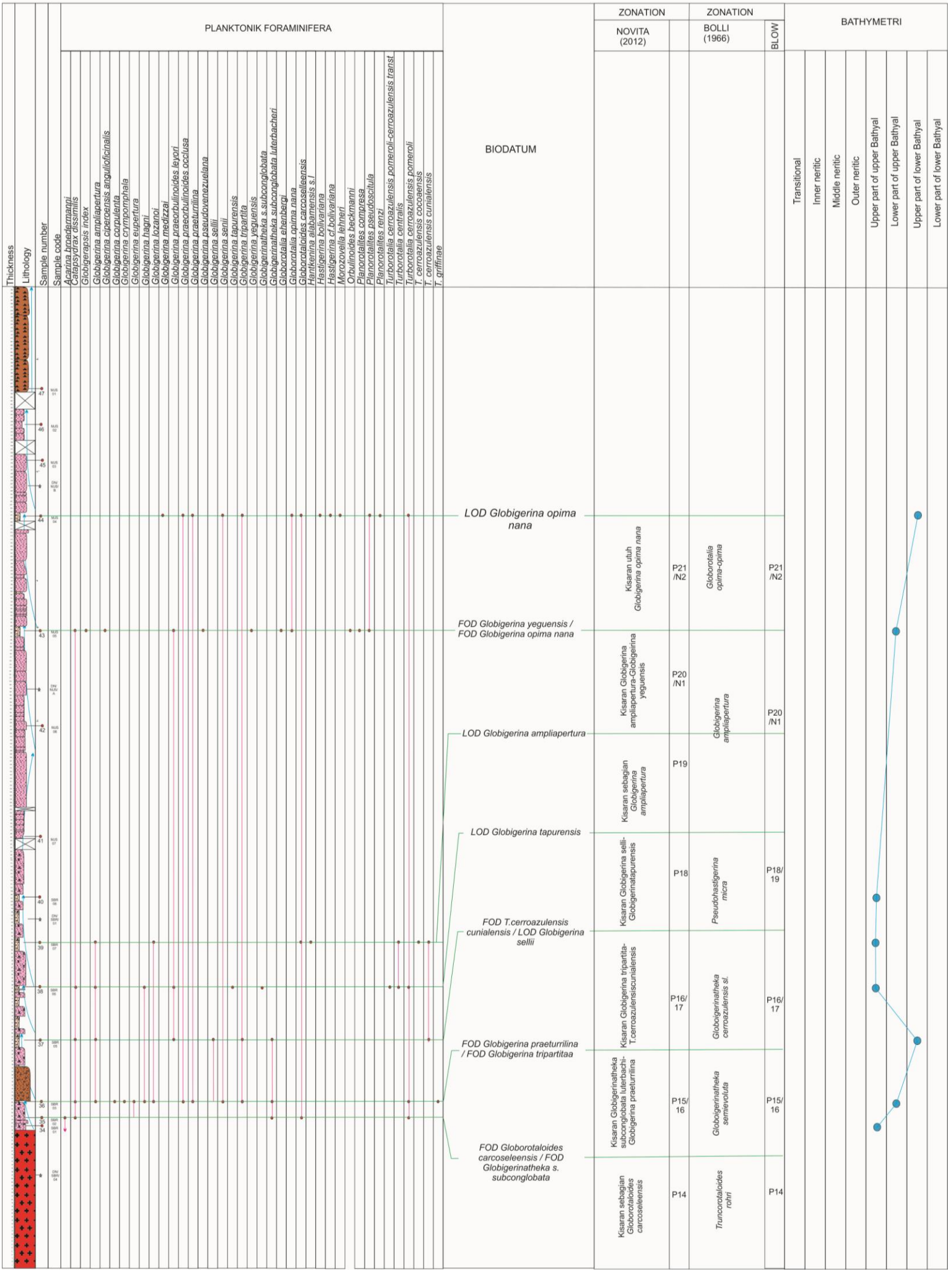
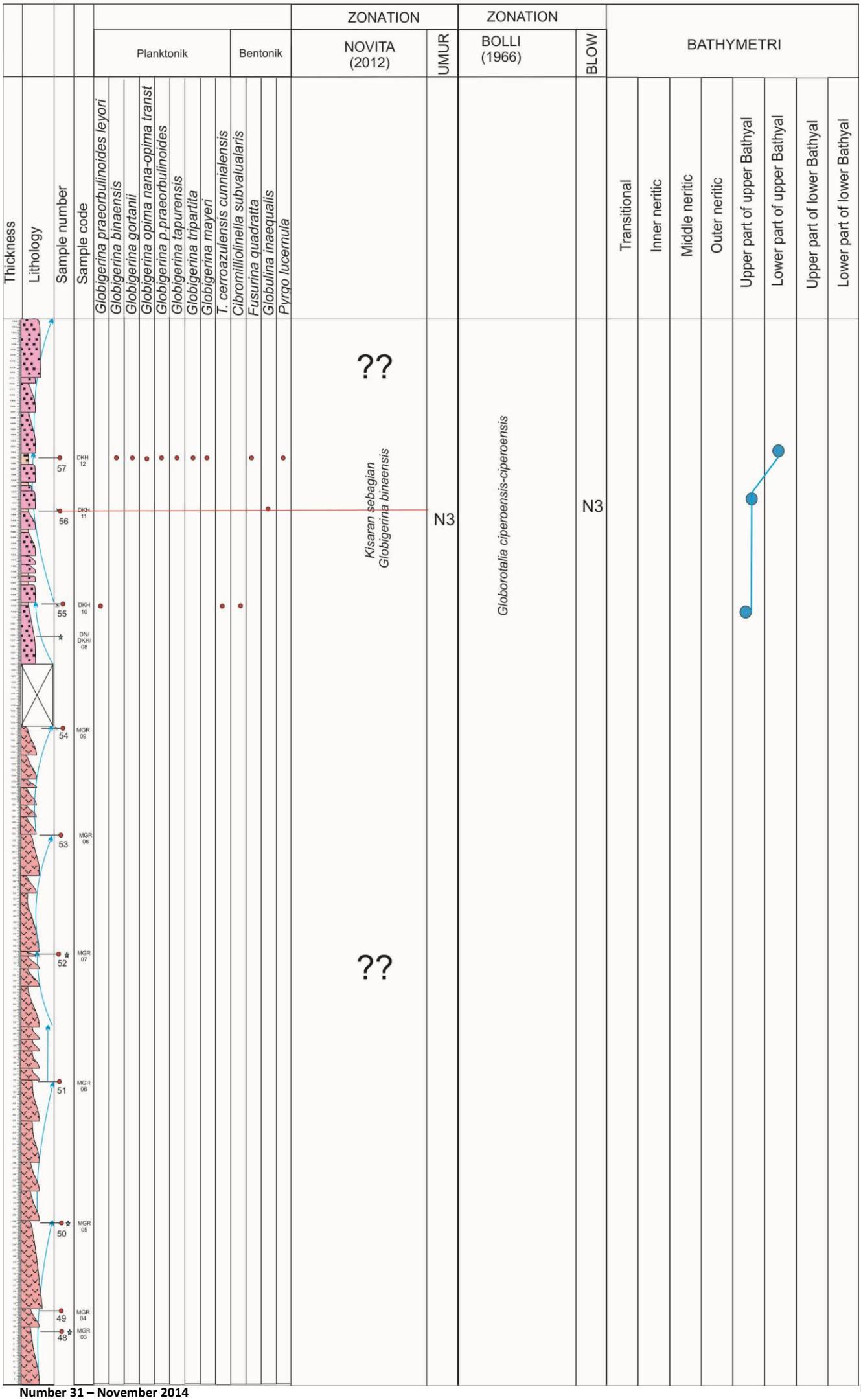
Globigerina p.praeorbulinoides
Globigerina praeorbulinoides leyori
Globigerina praeorbulinoides occlusa
Globigerina pseudoampliapertura
Globigerina pseudovenezuelana
Globigerina selli
Globigerina senni
Globigerina tapurensis
Globigerina triloculinoides
Globigerina tripartita
Globigerina venezuelana
Globigerina yeguensis
Globigerinatheka index tropicalis
Globigerinatheka index-index
Globigerinatheka mexicana kugleri
Globigerinatheka mexicana-mexicana
Globigerinatheka s.subconglobata
Globigerinatheka subconglobata curryi
Globigerinatheka subconglobata tuterbacheri
Globigerinoides primordius
Globigerinoides trilobus trilobus
Globorotalia mayeri
Globorotalia opima nana
Globorotalia opima nana-opima opima transition
Globorotalia opima-opima
Globorotaloides carcosellensis
Hastigerina cf.bolivariana
Morozovella lehneri
Planorotalites pseudoscitula
Pseudohastigerina dannillensis
T. cerroazulensis passagnoensis-pomeroli transt
Truncorotaliodes rohri
Turborotalia centralis
Turborotalia cerroazulensis frontosa
Turborotalia cerroazulensis pomeroli
T. cerroazulensis possagnoensis pomeroli
Turborotalia griffinae
Thickness
Lithology
Sample number
Sample code
BIODATUM
ZONATIONI
NOVITA (2012)
ZONATION
BOLLI (1966)
BLOW
BATHYMETRI
Non marine
Transitional
Inner neritic
Middle neritic
Outer neritic
Upper part of upper Bathyal
Lower part of upper Bathyal
Lower part of lower Bathyal
Upper part of lower Bathyal
LOD Globigerina venezuelana
LOD Globigerinoides primordius / FOD Globigerina binaensis
FOD Globigerina ciperoensis anguliosuturalis / FOD Globigerinoides primordius
FOD Globorotalia opima-opima / LOD Globorotalia opima opima
FOD Globigerina venezuelana / FOD Globorotalia opima opima
FOD Globorotalia opima nana / FOD Globigerina ampliapertura
FOD Globigerina yeguensis
FOD Globigerinatheka mexicana - mexicana / LOD T.cerroazulensis possagnoensis pomeroli transition
LOD Globigerina sennii
FOD Planorotalites peudoscitula / FOD Globigerina sennii
LOD Globigerinatheka subconglobata- subconglobata / FOD Globigerina medizzani
LOD Morozovella lehneri / LOD Globigerinatheka m. kugleri
LOD Globigerinatheka subconglobata curryii / FOD Morozovella lehneri
Kisaran Globigerina binaensis-Globigerina venezuelana
N5
Catapsydrax dissimilis zone
N5
Kisaran utuh Globigerinoides primordius
N4
Globigerinoides primordius zone
N4
Kisaran Globorotalia opima-opima-Globigerina ciperoensis anguliosuturalis
P22 /N3
Globigerina ciperoensis-ciperoensis zone
P22 /N3
Kisaran utuh Globorotalia opima-opima
P21 /N2
Globorotalia opima-opima
P21 /N2
Kisaran Globigerina ampliapertura-Globigerina venezuelana
Globigerina ampliapertura zone
P20 /N1
Kisaran Globigerina yeguensis-Globigerina opima nana
P18 /19
Pseudo-hastigerina micra
P18 /19
Kisaran T.cerroazulensis possagnoensis pomeroli trans-Globigerina yeguensis
P16 /17
Turborotalia Cerroazulensis s.l.
P16 /17
Kisaran Globigerina semi-Globigerinatheka m.mexicana
P15/ 16
Globigerinatheka semiinvoluta
P15/ 16
Kisaran utuh Globigerina sennii
P14 akhir
Kisaran Globigerina medizzani-Planorotalites pseudoscitula
P14 awal
Truncorotaliodes rohri
P14
Kisaran Globigerinatheka mexicana kugleri-Globigerinatheka s.subconglobata
P13
Orbulinoides beckmannii
P13
Kisaran utuh Morozovella lehneriotone
P12
Morozovella lehneri
P12
Kisaran sebagian Globigerinatheka s.curryi
P11
Globigerinatheka s.subconglobata
P11


PLANKTONIK FORAMINIFERA
Thickness
Lithology
Sample number
Sample code
Acarinina broedermanni
Catapsydrax dissimilis
Globigerapsis index
Globigerina ampliapertura
Globigerina cipercensis angulloficinalis
Globigerina corpulenta
Globigerina crympomphala
Globigerina eupertura
Globigerina hagni
Globigerina lozanoi
Globigerina medizzai
Globigerina praeorbulinoides leyori
Globigerina praeorbulinoides occlusa
Globigerina praeturrilina
Globigerina pseudovenezuelana
Globigerina sellii
Globigerina senii
Globigerina tapurensis
Globigerina tripartita
Globigerina yeguensis
Globigerinatheka s.subconglobata
Globigerinatheka subconglobata luterbacheri
Globorotalia ehenbergi
Globorotalia opima nana
Globoroloides carcoselleensis
Hantkenina alabamensis s.l
Hastigerina bolivariana
Hastigerina cf.bolivariana
Morozovella lehneri
Orbulinoides beckmanni
Planorotalites compresa
Planorotalites pseudoscitula
Planorotalites renzi
Turborotalia cerroazulensis pomeroli-cerroazulensis transt.
Turborotalia centralis
Turborotalia cerroazulensis pomeroli
T. cerroazulensis cocoaensis
T. cerroazulensis cunialensis
T. griffinae
BIODATUM
ZONATION
NOVITA (2012)
ZONATION
BOLLI (1966)
BLOW
BATHYMETRI
Transitional
Inner neritic
Middle neritic
Outer neritic
Upper part of upper Bathyal
Lower part of upper Bathyal
Upper part of lower Bathyal
Lower part of lower Bathyal
LOD Globigerina opima nana
FOD Globigerina yeguensis / FOD Globigerina opima nana
LOD Globigerina ampliapertura
LOD Globigerina tapurensis
FOD T.cerroazulensis cunialensis / LOD Globigerina sellii
FOD Globigerina praeturrilina / FOD Globigerina tripartitaa
FOD Globorotaloides carcoseleensis / FOD Globigerinatheka s. subconglobata
Kisaran utuh Globigerina opima nana
Kisaran Globigerina ampliapertura-Globigeirina yeguensis
Kisaran sebagian Globigerina ampliapertura
Kisaran Globigerina sellii-Globigerinatapurensis
Kisaran Globigerina tripartita-T.cerroazulensiscunialensis
Kisaran Globigerinatheka subconglobata luterbachi-Globigerina praeturrilina
Kisaran sebagian Globorotaloides carcoseleensis
P21 /N2
P20 /N1
P19
P18
P16/ 17
P15/ 16
P14
Globorotalia opima-opima
Globigerina ampliapertura
Pseudohastigerina micra
Globoigerinatheka cerroazulensis sl.
Globoigerinatheka semievoluta
Truncorotaloides rohri
P21 /N2
P20 /N1
P18/ 19
P16/ 17
P15/ 16
P14


Thickness
Lithology
Sample number
Sample code
Planktonik
Bentonik
Globigerina praeorbulinoides leyori
Globigerina binaensis
Globigerina gortanii
Globigerina opima nana-opima transt
Globigerina p.praeorbulinoides
Globigerina tapurensis
Globigerina tripartita
Globigerina mayeri
T. cerroazulensis cunnialensis
Cibromiliolinella subvalualaris
Fusurina quadratta
Globulina inaequalis
Pyrgo lucernula
ZONATION
NOVITA (2012)
UMUR
??
Kisaran sebagian Globigerina binaensis
N3
??
ZONATION
BOLLI (1966)
Globorotalia ciperoensis-ciperoensis
BLOW
N3
BATHYMETRI
Transitional
Inner neritic
Middle neritic
Outer neritic
Upper part of upper Bathyal
Lower part of upper Bathyal
Upper part of lower Bathyal
Lower part of lower Bathyal
57
DKH 12
56
DKH 11
55
DKH 10
DN/ DKH/ 08
54
MGR 09
53
MGR 08
52
MGR 07
51
MGR 06
50
MGR 05
49
MGR 04
48
MGR 03