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Depositional Environment of the Batuasih Formation on the Basis of Foraminifera Content: A Case Study in Sukabumi Region, West Java Province, Indonesia

Lingkungan Pengendapan Formasi Batuasih Berdasarkan Kandungan Foraminifera: Studi Kasus Daerah Sukabumi, Provinsi Jawa Barat, Indonesia

M. Hendrizan, Praptisih, and Purna S. Putra

Research Center for Geotechnology LIPI, Komplek LIPI, Gd. 70
Jln. Sangkuriang, Bandung, Indonesia

Abstract

The research was carried out on the sediments of the Batuasih Formation cropping out at Batuasih Village, Cibatu River, Padaarang Sukabumi. Data obtained from field observation, as well as foraminifera and sedimentology analyses conducted in the laboratory, were used to interpret its depositional environment. The investigation was focused on planktonic and benthic foraminiferal assemblages for depositional environment interpretation that might not be used by previous researchers. The Batuasih Formation is composed of black shaly claystone, where the lower part is rich in clay ball, and limestone intercalations in the upper part of the formation. In Cibatu Section, no clay balls is recognized in the lower part, but intercalations of limestone still occur. However, a contrast difference is found in Padaarang section, where green claystone interbeds with fine-grained sandstone. The Batuasih Formation conformably overlies the Walat Formation containing conglomerate. Foraminifera fossil found in the Batuasih Formation consists of bad preserved black benthic and planktonic foraminifera, more abundant towards the lower part of formation. Based on foraminifera assemblage comprising genus *Uvigerina, Cibicides, Elphidium, Operculina, Bulimina, Bolivina*, *Eponides*, and *Neoconorbina*, supported by sedimentology data, the Batuasih Formation was deposited in a shallow to deep marine environtment, during Early Oligocene (P19) time. Upwards to be the Rajamandala Formation, the depositional environment tends to be shallower gradually.

Keywords: Batuasih Formation, foraminifera, shallow - deep marine, Early Oligocene, Sukabumi

Sari

Kajian ini dilaksanakan pada batuan sedimen Formasi Batuasih di Desa Batuasih, Sungai Cibatu, Padaarang, Kabupaten Sukabumi. Data observasi megaskopis batuan di lapangan, serta analisis fosil foraminifera, dan sedimentologi yang dilaksanakan di laboratorium, digunakan sebagai bahan interpretasi lingkungan pengendapan. Investigasi ini difokuskan terhadap kandungan foraminifera plankton dan bentos untuk interpretasi lingkungan pengendapan, yang kurang diperhatikan oleh para peneliti terdahulu. Pada lintasan Batuasih, formasi ini tersusun oleh batulempung hitam, menyerpih, yang banyak mengandung bola lempung di bagian bawah dan sisipan batugamping di bagian atas. Di lintasan Cibatu, bola lempung di bagian bawah sudah tidak ada, tetapi sisipan batugamping masih tampak. Namun, perbedaan mencolok terlihat pada lintasan Padaarang yakni hadirnya batulempung kehijauan yang berselingan dengan batupasir sangat halus. Formasi Batuasih ini menindih selaras Formasi Walat yang mengandung konglomerat. Fosil foraminifera yang ditemukan didominasi oleh foraminifera bentos maupun plankton berwarna hitam, pengawetan buruk, yang semakin melimpah ke bagian bawah runtunan. Kandungan kumpulan foraminifera genus Uvigerina, Cibicides, Elphidium, Operculina, Bulimina, Bolivina, Eponides, dan Neoconorbina serta data sedimentologi mengindikasikan bahwa sedimentasi Formasi Batuasih terjadi pada lingkungan laut dangkal - laut dalam, dengan umur Oligosen Awal (P19). Lingkungan pengendapan ini ke arah atas, yaitu pada pada Formasi Rajamandala, semakin mendangkal secara berangsur.

Kata kunci: *Formasi Batuasih, foraminifera, laut dangkal - laut dalam, Oligosen Awal, Sukabumi*

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Corresponding Author: +6281809168799/hendrizan@geotek.lipi.go.id

Introduction

Background

The Batuasih Formation is an Oligocene marine sedimentary unit comprising claystone, marl, and shale. The formation is unconformably underlain by the Bayah Formation (Martodjojo, 1984; Darman and Sidi, 2000; and Clement and Hall, 2007). Tectonically, the deposition of Batuasih Formation included into the Bogor Trough System, was due to volcano-magmatic and compression influences. Martodjojo (1984) stated that lithologically, the formation had a similarity with the Cijengkol Formation in the South Banten. However, it is much thicker and more marine, and rich in planktonic foraminifera. To the east, in Cipanas (Saguling), Rajamandala region, some black marl outcrops have a close similarity with the Batuasih Formation. Those outcrops, the Cijengkol and Batuasih Formations (outcrop in Rajamandala included) have the same stratigraphical level.

In three different traverses, detailed studies had been carried out by Siregar *et al*. (1983) and Isnaniawardhani (1997). The first traverse is situated in Gunung Karang area, where a contact between the Rajamandala Formation and poorly bedded Batuasih Formation containing abundant planktonic foraminifera was recognized. On the basis of the planktonic foraminifera content, the age of formation ranges between Late Oligocene to Early Miocene or N3 - N4 Zone. In the second traverse, located around Batuasih Village, the rock unit is made up of dark grey claystone, poorly bedded, containing planktonic foraminifera fossils. The age of the formation is Middle - Late Oligocene (P19 - P21/ N2). Moreover, in the third traverse, located to the south, that is Pasir Bongkok, no Batuasih Formation can be recognized. Isnaniawardhani (1997) made a detailed biostratigraphic zonation on the basis of foraminifera and nannoplankton fossil content. The study was conducted from a branch of River Cibatu till a waterfall site nearby Pasirbintang limestone incineration. The nannoplakton zonation is divided into four zones with five subzones, whereas the foraminifera zonation comprises six zones, tending to indicate Late Oligocene to Early Miocene in age.

In the previous studies, the benthic foraminifera have not been used as a parameter in interpreting the depositional environment of Batuasih Formation. Isnaniawardhani (1997) stated that towards the upper part of Batuasih Formation, the depositional environment tended to be a deep marine, due to the sparse content of planktonic foraminifera, but rich in the benthic one. This condition becomes a good parameter in the depositional environment interpretation.

The aim of the study is to interpret the depositional environment of the Batuasih Formation. Therefore, the recent study is focused on ratio of planktonic and benthic foraminifera, as well as benthic foraminifera association in the Sukabumi region.

Regional Geology

Based on the Bemmelen's physiographic zones (1949), the studied area occupies the dome and middle depression ridge zones, characterized by folded mountainous series having axis direction of relatively east - west.

Stratigraphically, from older to younger, the studied area is made up of Walat, Batuasih, and Rajamandala Formation (Effendi *et al*., 1998; Figure 1). The Walat Formation consists of cross bedded quartz sandstone, quartzose conglomerate, carbonaceous claystone, lignite, and thin layers of coal. Upwards, the grain size is coarser, as cropping out in Mount Walat (nearby Cibadak) and its vicinity. The rock unit age is presummed to be Early Oligocene, occurring as the oldest unit recognized in the area, having thickness of 1,000 - 1,373 m. The formation is conformably overlain by the Batuasih Formation, comprising green marly claystone containing pyrite concretion. Assemblages of abundant micro- and macroforaminifera of probably Late Oligocene age were often recognized in some sites.

The Batuasih Formation unconformably underlies the Rajamandala Formation and Limestone Member of the Rajamandala Formation. The Rajamandala Formation is composed of tuffaceous marl, marly claystone, sandstone, and limestone lenses containing *Globigerina oligocaenica, Globigerina praebulloides, Orbulina, Lepidocyclina*, and *Spiroclypeus* fossils; whilst the Limestone Member consists of coral reefs with fossils *Lithothamnium* (Algae), *Lepidocyclina sumatrensis*, and *Lepidocyclina (Eulepidina) ephipioides* (Budiman, 1971; *in* Effendi *et al*., 1998). Those two sedimentary units having thickness of 1,100 m, are Late Oligocene to Early Miocene *in* age (Musper, 1939b; *in* Effendi *et al*., 1998).

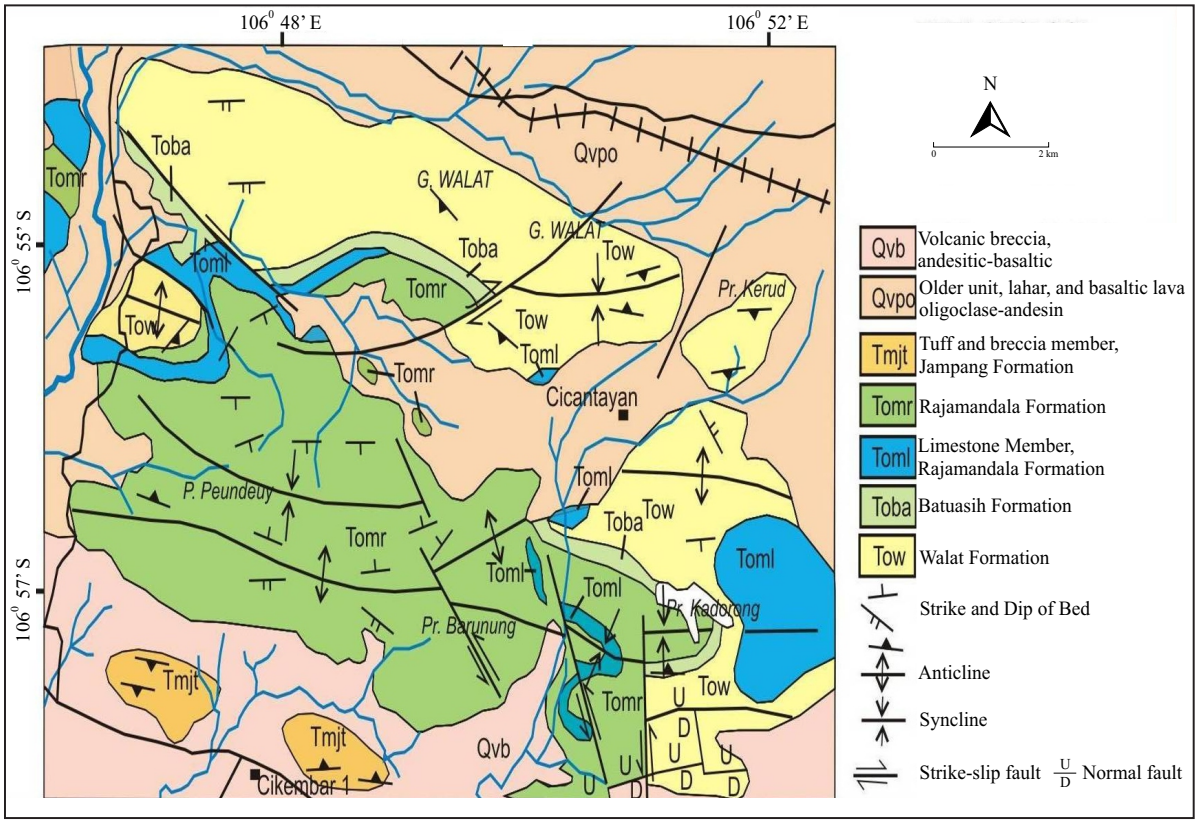

Figure 1. Geological map of part of Sukabumi Sheet (Effendi *et al*., 1998).

The Rajamandala Formation is unconformably overlain by the Tuff and Breccia Members of the Jampang Formation. Both members comprise dacitic tuffaceous sandstone, andesitic tuff, pumiceous tuff, and calcareous tuffaceous dacitic-andesitic breccia (Musper,1939b; in Effendi *et al*., 1998), and marly claystone. In places, limestone bed contains fossils *Trillina howchini, Lepidocyclina brouweri, Globorotalia mayeri,* and *Globorotalia fohsi barisanensis* (Kadar, 1972; *in* Effendi *et al*., 1998) indicating Early Miocene age was found. On top of the Tuff and Breccia Members of the Jampang Formation, lahar, andesitic-basaltic lava, and volcanic breccia overly unconformably.

Geological structures determined in the studied area consist of fault, fold, and joint. Fault developing, in general, is strike-slip types having directions of north - south, southwest - northeast, and northwest - southeast. Fold pattern developed occurs as anticline and syncline within east - west, southwest - northeast, and northwest - southeast directions.

Methodology

Batuasih Village is choosed as a type locality of the Batuasih Formation added with some areas represented the formation. The Batuasih Formation in Batuasih Village is underlain by the Walat Formation and overlain by the Rajamandala Formation. Measured sections were carried out on May, 2008. During the activity, twenty rock samples were collected from the formation, consisting of blackish grey claystone and yellowish grey siltstone.

Some laboratory procedures have been applied for rock sample analysis. Sample were crushed and ground to gain fine sizes, then put into plastic/brass cup. After that, the samples were cleaned with H_2O_2 to remove the foraminifera shell from impurities. After 24 hour- soaking, the sample was cleaned with water and then it was sieved by using 16 mesh, 100 mesh, and 200 mesh sieves. Then, the samples was dried inside an oven within temperature of 50^0C for 12 hours. Finally, the sample was put inside plastic bags for picking and fossil determination needs.

Methods developed by Loeblich and Tappan (1988, 1994), Le Roy (1941, 1944), Van Marle (1991), and Yassini & Jones (1995) were used for benthic foraminifera taxonomy analysis; whilst planktonic foraminifera taxonomy was based on Blow (1969), Postuma (1971), and Bolli and Saunders (1985) ones. Furthermore, quantitative analysis based on van Gorsel method (1988) was used to interpret the depositional environment. Moreover, microphotograph was gained from Scanning Electron Microscope (SEM) mode.

Results of Analysis

Only seven of twenty samples collected from Batuasih, Cibatu, and Padaarang traverses (Figure 2) contain foraminifera fossil. The fossil dominated by poorly preserved blackish grey foraminifera led to the difficulties in determination process.

Batuasih Traverse

The Batuasih Formation occurring in the Batuasih traverse is 36 m thick, and is dominated by blackish grey claystone. In its upper part, fine-grained limestone intercalations were recognized; whilst the lower part of formation contains clay balls of 5 - 7 cm in diameter and calcite veins. Along the traverse, fossils were only recognized in samples BS 04, BS 05, and BS 07 (Figure 3). The fossils having black colour and indistinct shell morphology, are poorly to well preserved. This characteristic tends to indicate the foraminifera fossils have undergone transportation processes. Ratio of planktonic to benthic foraminiferas within sample BS 07 collected from the lowest part of unit is 70.7 %. The benthic foraminifera comprises eight species including *Uvigerina peregrina* (Figure 4a), *Bolivina sp.*, *Cibicides refulgens*, *Pseudonodosaria sp.*, *Cibicides sp.*, *Rutherfordoides mexicanus*, *Uvigerina porrecta*, and *Neoconorbina terquemi* (Figure 4b). On the other hand, the planktonic foraminifera is composed of nine species, *i.e. Globigerina venezuelana*, *Globigerina praeturritilina*, *Globigerina tapuriensis* (Figure 4c), *Globorotalia opima*, *Globigerina tripartita* (Figure 4d), *Globigerina ampliapertura*, *Globigerina praebulloides* (Figure 4e-4f), *Catapsydrax dissimilis*, and *Globigerina ciperoensis* (Figure 5a). Benthic foraminifera content and ratio of planktonic to benthic foraminiferas indicate an upper bathyal - outer neritic depositional environment; whilst planktonic foraminifera shows age of Early Oligocene (P19). Sample BS 05 having ratio of planktonic to benthic foraminiferas of 60%, contains nine planktonic foraminifera species, those are *Globigerina tapuriensis*, *Globoquadrina altispira*

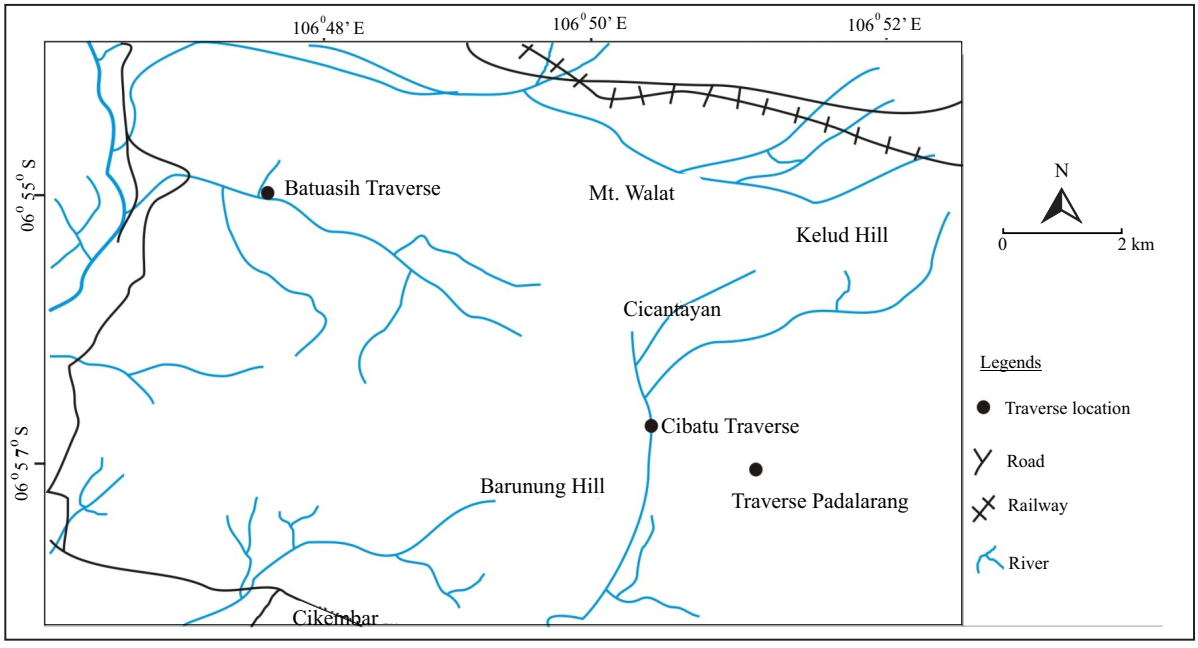

Figure 2. Locality map of outcrop studied of the Batuasih Formation, Sukabumi.

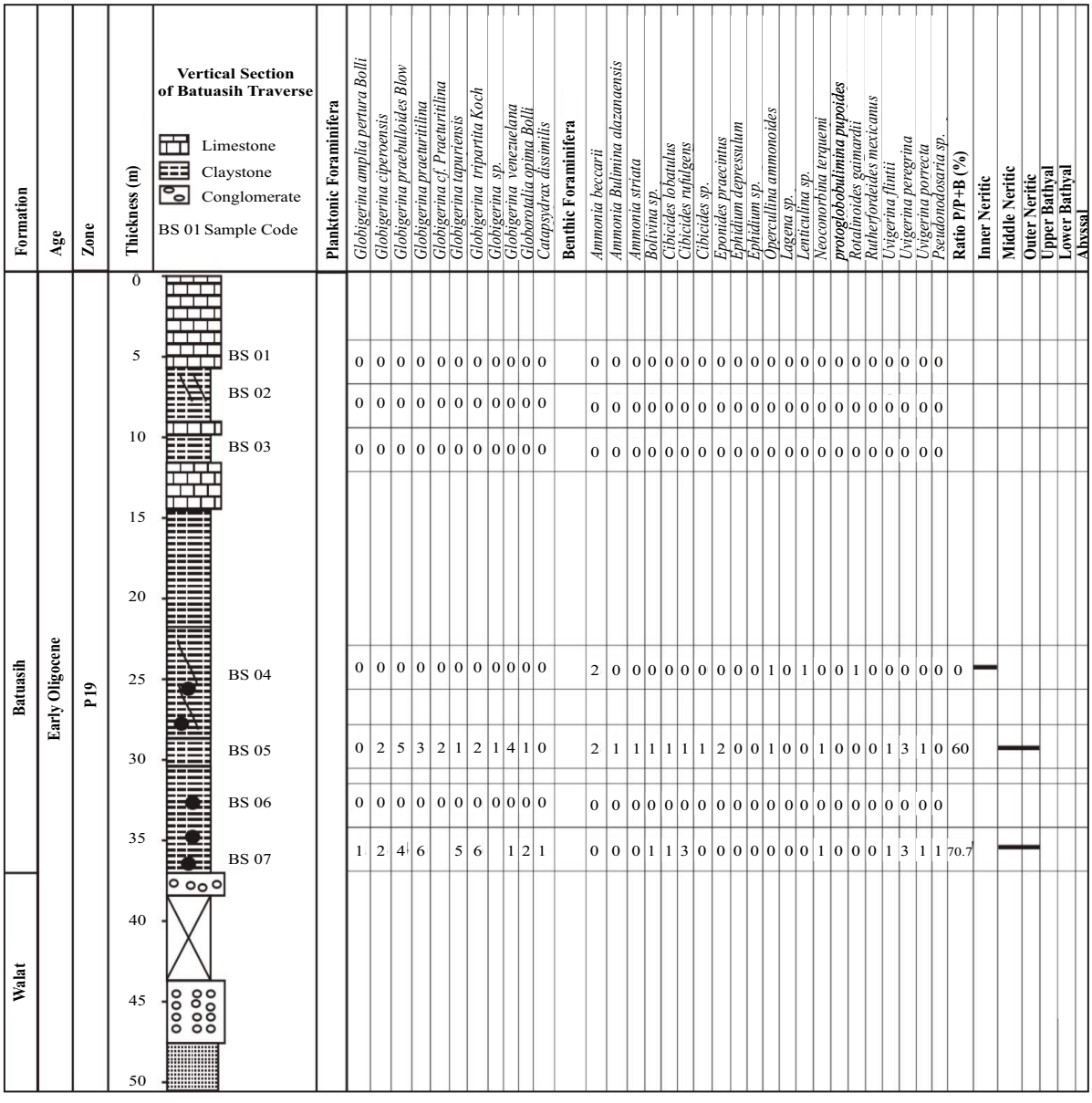

Figure 3. Foraminifera distribution in the Batuasih traverse.

(Figure 5b), *Globigerina praebulloides*, *Globigerina cf. praeturritilina*, *Globigerina tripartita*, *Globigerina ciperoensis*, *Globigerina praeturritilina*, *Globorotalia opima opima* (Figure 5c), and *Globigerina sp.*, showing Early Oligocene age (P19) and fourteen benthic foraminifera species, *i.e. Bulimina striata, Eponides praecintus, Cibicides lobatulus* (Figure 5d-5e), *Bulimina alazanensis, Lagena sp.* (Figure 5f), *Uvigerina peregrina, Pseudonodosaria sp.*, *Cibicides sp.*, *Elphidium depressulum*, *Elphidium sp.*, *Bolivina sp.*, *Uvigerina flintii*, *Protoglobobulimina pupoides*, and *Cibicides refulgens*. Those benthic foraminifera contained within sample BS 05 was deposited in an outer to middle neritic zone; whilst in sample BS 04 only three species of benthic foraminifera were recognized, those are *Ammonia beccarii* (Figure 6a), *Operculina ammonoides* (Figure 6b), and *Lenticulina sp.* Those three species tend to indicate a deep neritic depositional environment (low tide to -30 m). The planktonic foraminifera which is more abundant

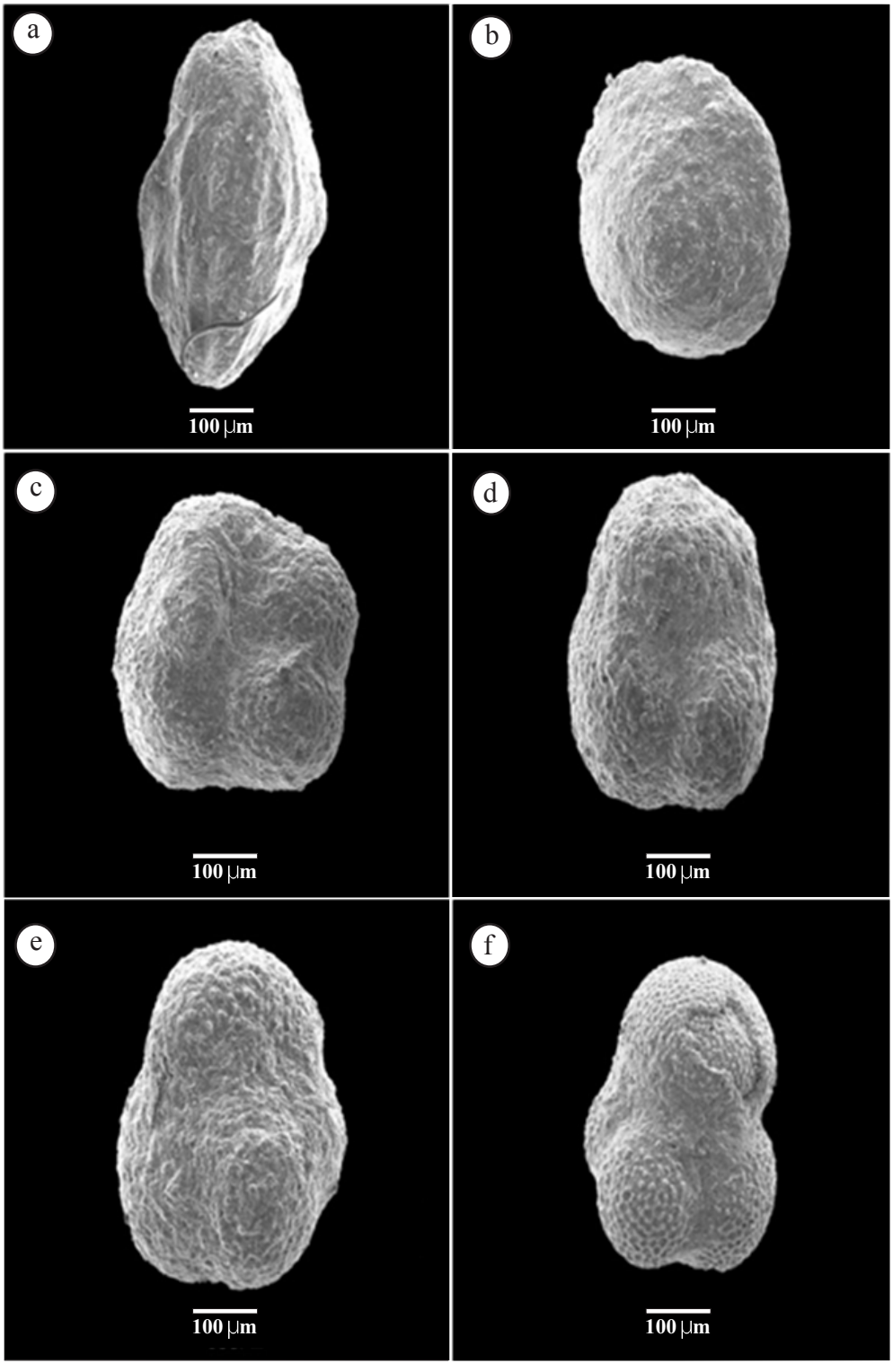

Figure 4. a. *Uvigerina peregrina;* b. *Neoconorbina terquemi;* c. *Globigerina tapuriensis;* d. *Globigerina tripartita;* e. *Neoconorbina terquemi;* f. *Globigerina praebulloides.*

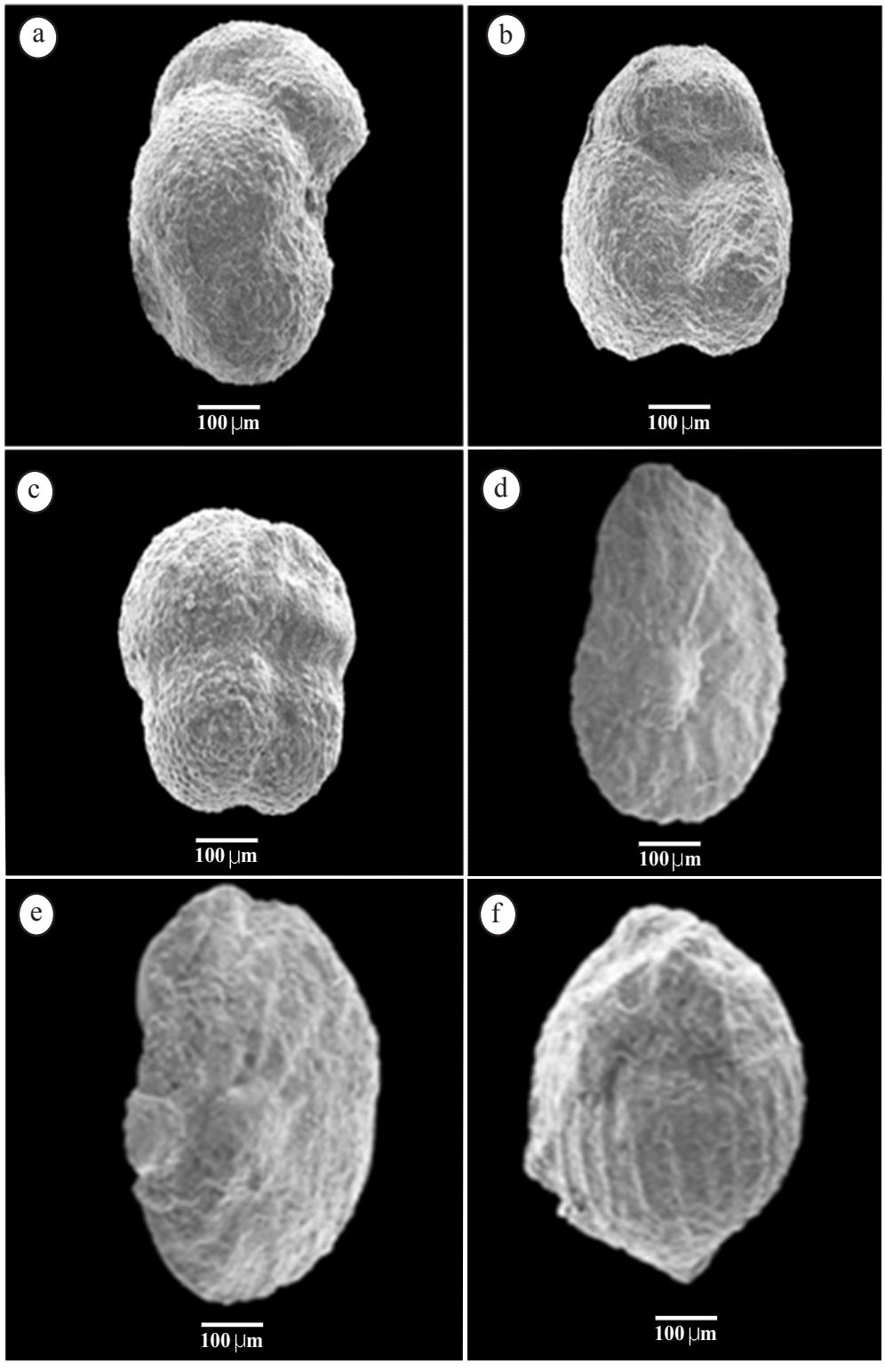

Figure 5. a. *Globigerina ciperoensis;* b. *Globoquadrina altispira;* c. *Globorotalia opima;* d-e. *Cibicides lobatulus;* f. *Lagena sp.*

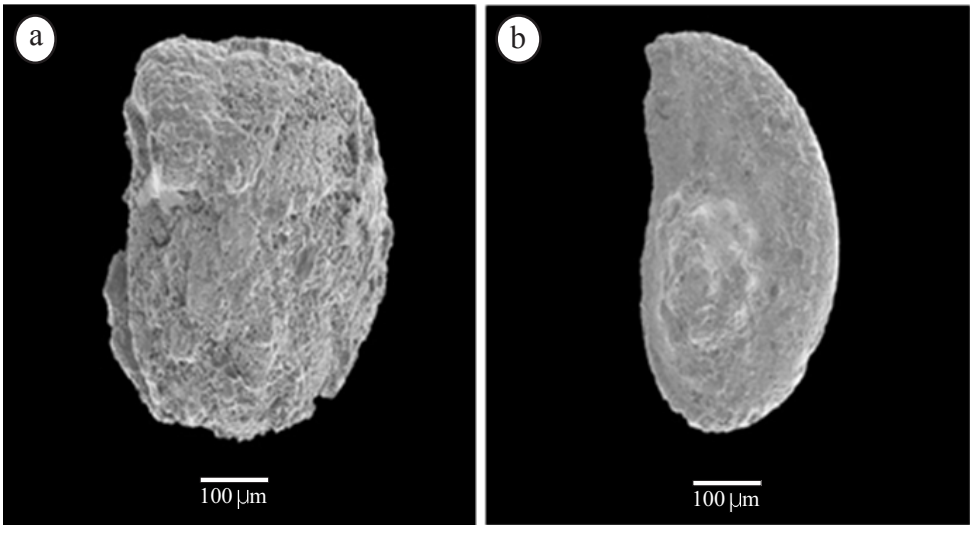

Figure 6. a. *Ammonia beccarii;* b. *Operculina ammonoides.*

towards the lower part of Batuasih Formation, is an indication that downwards the depositional environment is a more deeper marine.

Cibatu Traverse

In Cibatu traverse, the Batuasih Formation has a thickness of 113 m, but about 10 m of it is covered by River Cibatu water, so it can not described in detail. In this area, blackish grey claystone is very dominant, only a little massive limestone intercalation which is 50 cm is cropped out at the upper part of Batuasih Formation. Meanwhile, at the lower part clay ball was not found (Figure 7). In Figure 7 showing the distribution of foraminifera, CB 02 is an example of the lowest place where the foraminifera fossils were found with the ratio of eleven planktonic foraminifera and six benthic foraminifera of 79.45%. The detected benthic foraminifera are E*lphidium advenum, Eponides praecintus, Lenticulina sp.*, *Ruakitoria magdaliformis,* and *Bannerella sp.* The benthic foraminifera assemblage indicates that the depositional environment is outer neritic. The planktonic foraminifera in these samples include *Globoquadrina altispira, Globigerina praebulloides, Globigerina tripartite, Globigerina praeturritilina, Globigerina yeguaensis* (Figure 8a), *Globorotalia opima opima, Globigerinoides sp., Globigerina sp., Globigerina tapuriensis, Globoquadrina ciperoensis*. These planktonic foraminifera show the Early Oligocene age (P19). Sample CB 04 has a ratio of the amount of planktonic foraminifera and benthic foraminifera of 33.3%. Benthic foraminifera content as *Cibroelphidium sp.* and *Eponides praecintus* show middle neritic depositional environment; whilst planktonic foraminifera *Globigerina tapuriensis* shows the Early Oligocen age (P19). Meanwhile, sample CB 05 only has gastropoda fossils showing a deep neritic environment.

Padaarang Traverse

Batuasih Formation cropped out in Padaarang area has a thickness of 2.56 m. At this traverse no blackish grey claystone was found but it had changed to become brownish grey claystone alternating with fine to very fine grained sandstone (Figure 9). Sample collecting at this traverse was very detailed, yet only one layer contains fossils. Foraminifera distribution is shown on Figure 9, *i.e.* rock sample PR 03B. In this sample only planktonic foraminifera fossils were found, *i.e. Globigerina yeguaensis, Globorotalia opima opima, Globorotalia opima nana, Globoquadrina sp.*, without benthic foraminifera. The ratio of planktonic and benthic foraminifera amounting 100% shows that PR 03 B was in the outer neritic environment. The foraminifera fossil assemblage shows an age of Early Oligocene (P19). This formation is presumed to be shallower to the upper part of the Batuasih Formation. Towards the upper part no more fossils were found, with depositional environment of shallower marine.

Discussion

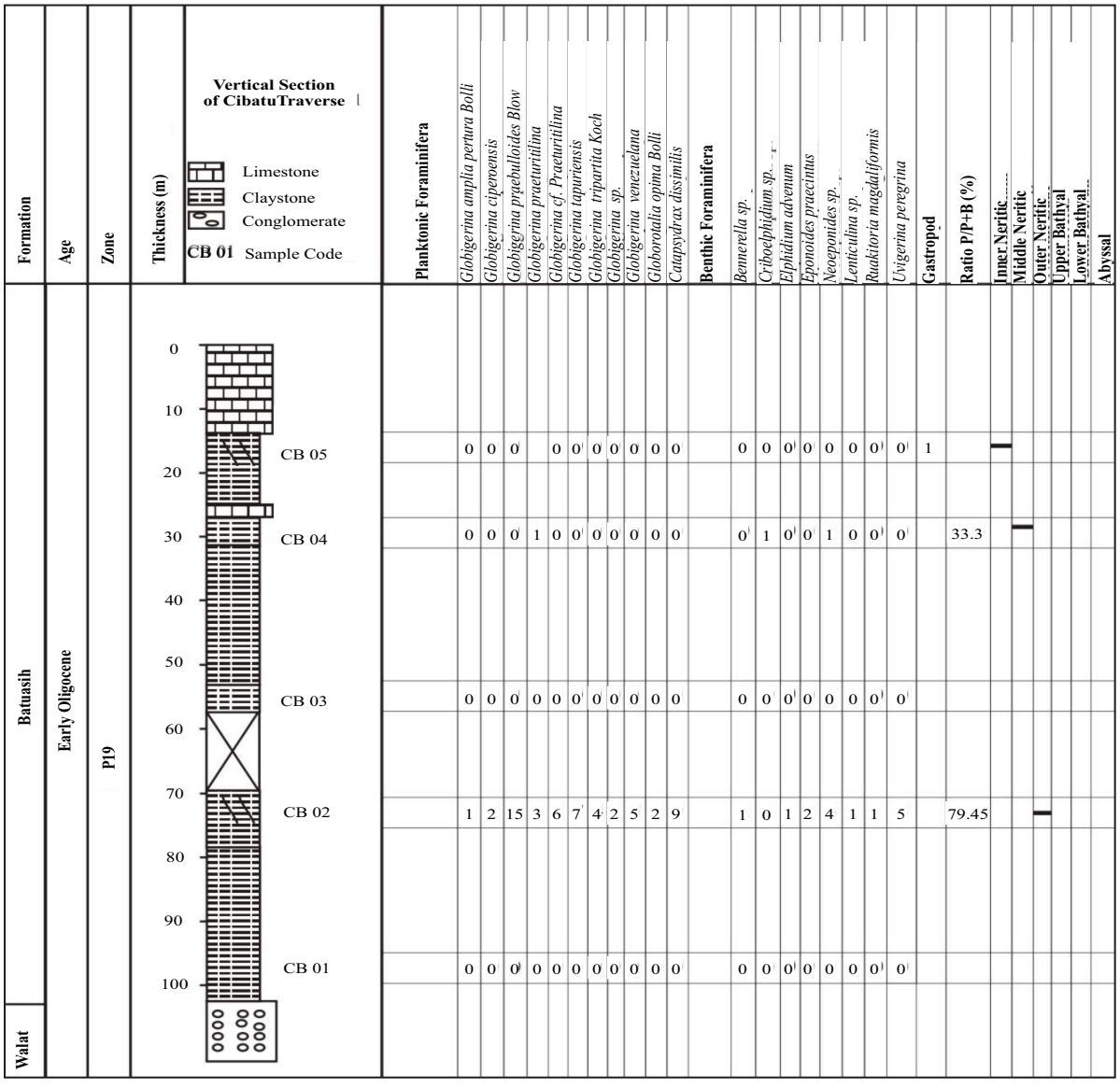

Figure 7. Foraminifera distribution in the Cibatu traverse.

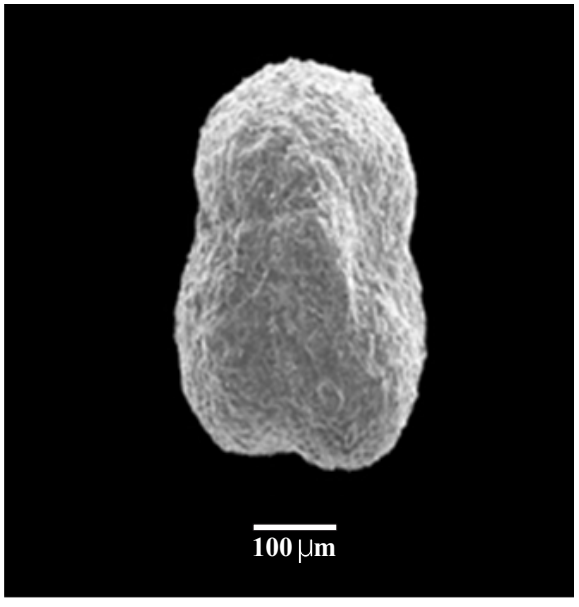

Figure 8. *Globigerina yeguaensis.*

Batuasih Formation in Sukabumi region located at the Batuasih, Cibatu, and Padaarang traverses shows a shallow to deep marine environment, ranging from deep neritic to upper bathyal. This is indicated by the ratio of the increasing amount of planktonic and benthic foraminifera towards the lower of the Batuasih Formation. At the Batuasih and Cibatu traverses, the lithology of this formation is relatively similar; although Batuasih traverse contains clay balls at the lower part; whilst at Padaarang traverse greenish claystone is alternating with fine grained sandstone. Sedimentary rocks at Batuasih and Cibatu traverses also show abundance of both planktonic and benthic foraminifera contents compared to the Padaarang traverse. Foraminifera contents at sample BS 07 as *Uvigerina porrecta*, *Uvigerina peregrina, Cibicides refulgens, Bulimina alazanensis*, and *Elphidium advenum* are indications of upper bathyal to outer neritic environment. This environment has been narrower to the upper part (BS 05) to become outer to middle neritic indicated by the species contents of *Eponides praecintus, Cibicides refulgens, Elphidium depressulum, Cibicides sp.*, and *Uvigerina peregrine*. Furthermore, sample BS 04 shows deep neritic environment indicated by the presence of *Operculina amonoides* fossils. Sedimentary rocks at Cibatu traverse shows outer neritic environment indicated by fossil contents of *Eponides praecintus, Uvigerina peregrina*, and *Elphidium advenum* found in sample CB 02. Towards the upper part, the found of *Elphidium advenum* and *Eponides praecintus* fossils in sample CB 04 indicates that the sedimentary environment of this formation is shallower towards middle neritic. Meanwhile, in sample CB 05 as the lowest part only gastropoda was found which shows deep neritic depositional environment; while at Padaarang traverse planktonic foraminifera were the only available content. The depositional environment of the top part of this formation is outer neritic at the lower part, which then shallower towards the upper part.

The analysis of depositional environment based on foraminifera fossil content gives a description that Batuasih Formation was deposited in a regression phase in Early Oligocene, precisely in deep to shallow marine environment (bathyal to deep neritic). Correlation of the three traverses shows that Batuasih traverse is the deepest then shallower at the Padaarang traverse.

The above condition gives a difference in interpreting depositional environment as described by previous worker (Isnaniawardhani, 1997; Martodjojo, 2003). Rock characteristic and the abundance of forminifera as well as nannoplankton were as the base in determining the deposional environment. They said that this formation was deposited in a transition environment with a reduction condition at the lower part. Foraminifera contents at the lower part of this formation generally show that towards the upper part, the environment is deep marine. Yet, the author found abundance of foraminifera, both planktonic and benthic, that are richer towards the lower part. Clement and Hall (2007) said that Batuasih Formation was composed of grey/green claystone that was poor in fossils, but it was deposited in a shalow marine or lagoon system based on the flora content as fresh till brackish water pollen.

Foraminifera contents found in the three traverses in Sukabumi region show that the depositional environment of this formation is more detailed that was not specifically described by previous workers (Isnaniawardhani, 1997; Martodjojo, 2003; Clement and Hall, 2007). The Batuasih Formation is Early Oligocene in age (P19) based on the presence of *Globoratalia opima opima*, but there is no guide

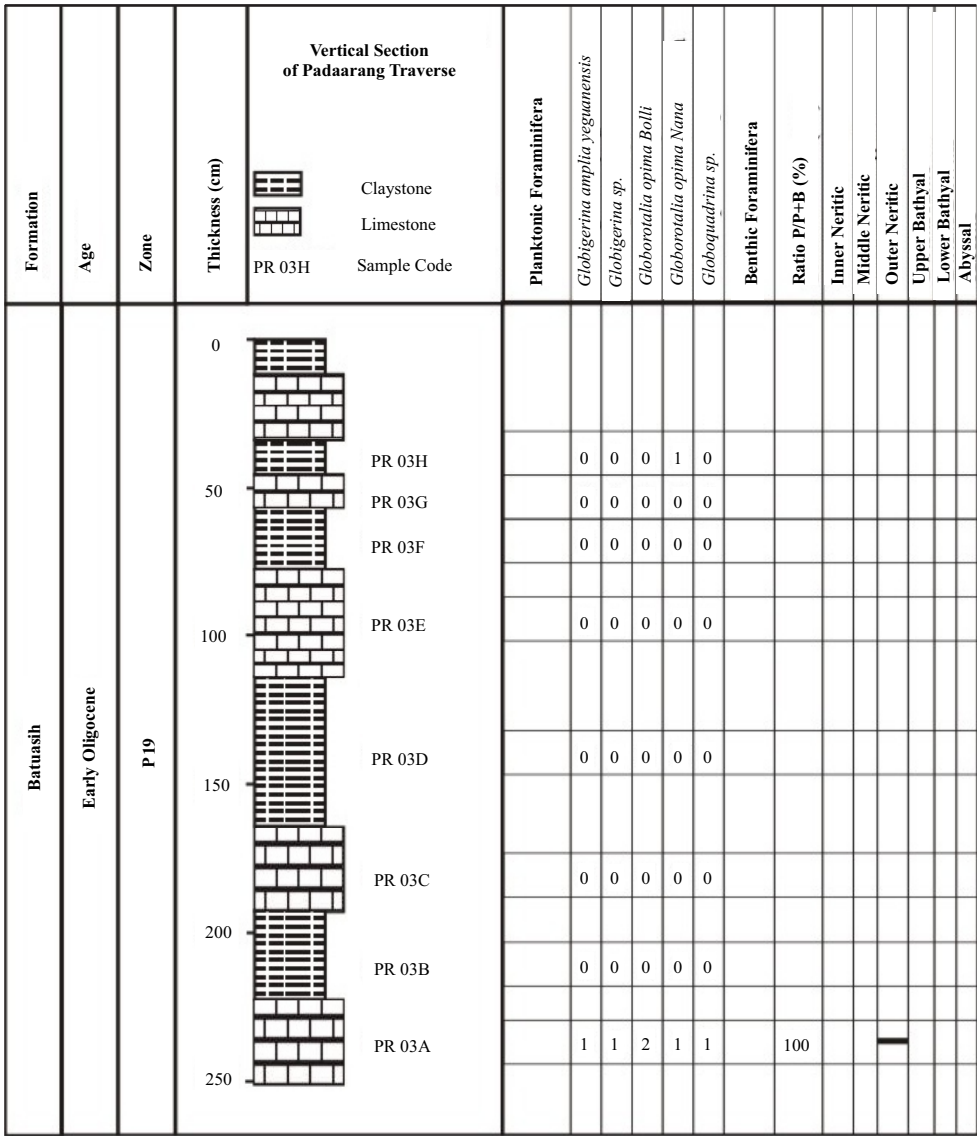

Figure 9. Foraminifera distribution in the Padaarang traverse.

fossil for the upper boundary of this formation. The discussion concerning the age of Batuasih Formation had been carried out by Siregar *et al*. (1983), Martodjojo (1984), and Isnaniawardhani (1997), while the author did not discuss the age of this Batuasih Formation in detail.

Conclusion

Batuasih Formation is shallow till deep marine sediments that had undergone a regression in Early Oligocene (P19). This is characterized by the ratio of the amount of both planktonic and benthic foraminifera that is around 0 - 100% towards the lower part of this formation, and also based on benthic foraminifera association. The Batuasih traverse show an upper bathyal till outer neritic depositional environment that was shallower towards the upper part to become deep neritic, while Cibatu traverse shows outer neritic at the lower part, and shallower towards the upper part to become deep neritic. Meanwhile, at the Padaarang traverse, although the presence of planktonic foraminifera fossils is only a little, this traverse is presumed to have been at the outer neritic. The three traverses show that the depositional environment of Batuasih Formation towards the upper part was shallower. The Batuasih traverse is a deep marine environment, and shallower towards the Padaarang traverse containing relatively rare planktonic and benthic foraminifera.

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