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The Planktonic Foraminifera in Well Bodjonegoro-1 of Java

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With 1 figure in the text, 1 table and 1 plate

CONTENTS

INTRODUCTION

Well Bodjonegoro-1, drilled in 1934 by the Bataafsche Petroleum Maatschappij North of Bodjonegoro on the Solo River about 90 km West of Surabaia, Java, reached a depth of 2025 metres. It penetrated Pliocene to Lower Miocene sediments of mostly open sea character, belonging to the Kalibeng and possibly also to the Rembang beds. Most of the section is very rich in planktonic Foraminifera but contains also variable percentages of benthonic Foraminifera and other microfossils such as Ostracoda (Kingma, 1948). The well was almost continuously cored between 101 and 2025 metres and therefore provides an outstanding profile for the study of the Foraminifera and their stratigraphic distribution. The stratigraphy in the area of Tjepu-Bodjonegoro-Surabaia is rather complicated, due to many changes in facies. Moreover, many terms have originally been used as lithological units, but have also been applied in the sense of biostratigraphic zones.

In the Tjepu area the *Globigerina* bearing beds are subdivided in ascending order into Wonotjolo, Ledok and Mundu. The Rembang beds, which underly the Wonotjolo are foraminiferal limestones and marls rich in *Cycloclypeus*, *Lepidocyclina* and *Miogypsina*. Under favourable conditions Wonotjolo and Ledok may contain the same Miocene Foraminifera. Mundu, which is the uppermost part of the *Globigerina* marls is considered Pliocene.

In the northern Rembang area there is an unconformity between the Lower Miocene Rembang beds and the Pliocene «Karren»-limestone. In the Bodjonegoro area Miocene and Pliocene are deposited in an open sea *Globigerina* marl sequence and are referred to as Rembang (Miocene) and Kalibeng (Pliocene); however, the Rembang beds by definition are characterized by larger Foraminifera and mollusks (see also Van Bemmelen, 1949 and Boomgart, 1949). For further informa-

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tion on the lithology and stratigraphy of the Kalibeng and Rembang beds reference is made to the publication «Smaller Foraminifera from Bodjonegoro (Java)» by BOOMGART (1949).

The benthonic and planktonic Foraminifera of Bodjonegoro-1 were described, figured and their stratigraphic distribution shown in the above mentioned publication by BOOMGART. Planktonic Foraminifera have in the meantime become much better known and recognised as excellent index fossils and are now widely used for stratigraphic zonation and correlation.

No similarly complete Lower Miocene to Pliocene section rich throughout in planktonic Foraminifera is known to the author. Bodjonegoro-1 therefore offered a unique opportunity to restudy the planktonic Foraminifera in the light of present day knowledge and to check how the occurrences and stratigraphic distribution of the Miocene to Pliocene species and subspecies of a tropical western Pacific province compare with those of the Caribbean area, where most of them were first described; in Trinidad those of the Lower and Middle Miocene (BOLLI, 1957), in Venezuela and Jamaica those of the higher Miocene and Pliocene (BOLLI & BERMUDEZ, 1965). This study is the first successful application to an Indonesian section of the Lower Miocene to Pliocene zonation established in the Caribbean.

After penetrating a Pliocene and Upper and Middle Miocene sequence, Bodjonegoro-1 bottomed in the lower Miocene *Globigerinatella insueta* zone. All the planktonic zones recognised in Trinidad, from the *Globigerinatella insueta* zone to the *Globorotalia menardii* zone, can be distinguished in Bodjonegoro-1. In addition, a *Globigerinoides ruber* zone, between the *Globorotalia fohsi robusta* zone below and the *Globorotalia mayeri* zone above, is proposed as new. The *Globorotalia acostaensis* to *Globoquadrina altispira altispira/Globorotalia crassaformis* zones, recently proposed by BOLLI and BERMUDEZ (1965), could also be recognised in upward continuation of the *Globorotalia menardii* zone. The highest two zones of these authors, the *Globoquadrina altispira altispira/Globorotalia truncatulinoides* and the *Globorotalia truncatulinoides/Globorotalia inflata* zones, could not be distinguished in Bodjonegoro-1 due probably to different environmental conditions.

56 planktonic foraminiferal species and subspecies are recognised and are plotted in table 1, compared with 14 described by BOOMGART in 1949. Two, *Globigerinoides emeisi* and *Globorotalia mohleri*, are new. Coiling patterns of a number of species are plotted in table 1, some were already described by BOLLI (1964), the others are briefly discussed here. The known species and subspecies are not described. However, some remarks are made on a number of species of stratigraphic interest and a few selected species are illustrated in addition to the two new species. Representative specimens of each species and subspecies are deposited at the Museum of Natural History, Basel (numbers C 24477–C 24536).

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THE PLANKTONIC ZONES

This is a first attempt to apply the zonation proposed by BOLLI (1957) and BOLLI & BERMUDEZ (1965) for the Caribbean province to a Lower Miocene to Pliocene section in the tropical western Pacific. Some earlier, stratigraphically more restricted attempts that use planktonic Foraminifera for zonation in the Pacific area have already been briefly reviewed by BOLLI (1964). In addition to these, reference is made here to VISSER & HERMES (1962) who offer a zonation based on planktonic Foraminifera for the Tertiary and Quaternary of New Guinea.

For the stratigraphic interval Paleocene to Pliocene, they distinguish fewer zones than are recognised in the Caribbean area and in Bodjonegoro-1 of Java. This appears to be due largely to the less complete sections that were available to them in New Guinea. Several of VISSER & HERMES' zones, in particular the older ones, are rather poorly defined. All zones of these authors are listed in the following, the definition of the younger ones, which are of special interest for the Bodjonegoro-1 section, are given in addition.

VISSER & HERMES place the Paleocene/Eocene into a single *Globorotalia* zone, divided into three subzones (from bottom to top): *Globorotalia membranacea* (=*Globorotalia ehrenbergi*, see remarks in BOLLI 1957b, p. 77), *Globorotalia velascoensis* and *Globorotalia centralis*. The *Globorotalia* zone is followed by a *Globigerina* zone subdivided into a lower, *Globigerina venezuelana* and an upper, *Globorotalia fohsi* subzone. Above the *Globigerina* zone lies the *Orbulina* zone with the *Orbulina universa*, *Globorotalia mayeri* and *Globigerina dubia* subzones. A fourth and highest zone is named *Pulleniatina* zone; it includes a lower, *Pulleniatina obliquiloculata*, a middle, *Globoquadrina conglomerata* (which according to VISSER & HERMES' fig. 63 on enclosure 17 appears to the author to be a typical *Globoquadrina altispira altispira*) and an upper, *Globigerinoides rubra* subzone. The *Pulleniatina obliquiloculata* subzone falls, according to the authors, between the first occurrence of the zonal marker and the first occurrences of *Globigerinoides ruber*, which is the second appearance of the latter, as discussed by BOLLI (1964 and in this paper). Such a subzone would in Bodjonegoro-1 fall between the first occurrence of *Pulleniatina obliquiloculata* at 368 metres and the base of the second appearance of *Globigerinoides ruber* at 324 metres. The *Globoquadrina conglomerata* subzone is defined by the first *Globigerinoides ruber* and the last occurrence of the subzonal marker. Such a subzone ranges in Bodjonegoro-1 from 324 to 216 metres. The base of VISSER & HERMES' *Globigerinoides rubra* subzone coincides with the extinction of their *Globoquadrina conglomerata*. The top is not clearly defined, the authors indicate that the subzone may go on to Recent. In Bodjonegoro-1 it would range from 216 metres to the highest core at 101 metres. The *Globigerinoides rubra* subzone of VISSER & HERMES is thus younger than the new Middle Miocene *Globigerinoides ruber* zone proposed in this paper, which lies between the *Globorotalia fohsi robusta* and the *Globorotalia mayeri* zone.

BOOMGART (1949, pp. 29–32) offers a division of the Bodjonegoro-1 section based on benthonic Foraminifera. He distinguishes from bottom to top the six zones A–F; zones A and C are each divided into two subzones. The base of each of BOOMGART's subdivisions is characterised by the first occurrence of certain benthonic Foraminifera. The zones are described in his text but are not used on the distribution chart.

The prime purpose of the present study is to compare the Indonesian planktonic foraminiferal fauna of Bodjonegoro-1 and its stratigraphic distribution with that already known from the Caribbean province, in particular Trinidad, Venezuela and Jamaica. As a whole the fauna and distribution patterns were found to compare well between these far distant tropical provinces; the few exceptions being due to stratigaphic breaks, condensation or differing environmental conditions. Some faunal, zonal and formational correlations of the Upper Miocene to Pliocene part of the section have already been discussed in the papers by Bolli (1964) and Bolli & Bermudez (1965).

The following notes illustrate the more important characters of each zone. They also point out some similarities and differences between the corresponding zones in Java and the Caribbean. They should be read in conjunction with the distribution chart of the Bodjonegoro-1 planktonic Foraminifera in table 1 and with text-figure 1 which gives the occurrence of the discussed zones in Java, Trinidad, coastal north-western Venezuela (Falcón), coastal north-eastern Venezuela and Jamaica. Text-figure 1 shows clearly how much more complete the Lower Miocene to Pliocene section of Bodjonegoro-1 is than any known from the Caribbean area.

Globigerinatella insueta zone (1914.2–2025 m)

The fauna is practically identical with that found in the same zone of the Cipero formation of Trinidad. All species, including *Globigerinoides bisphaerica* and *G. transitorius*, occur practically throughout the zone. The zonal marker was only seen in the upper part of the interval.

Globorotalia fohsi barisanensis zone (1842–1914.2 m)

This interval compares with the basal part of this zone as known from the Cipero formation of Trinidad. *Porticulasphaera glomerosa curva* is present in the lower part, *P. glomerosa glomerosa* and *P. glomerosa circularis* in the upper part of the interval. *Orbulina* appears only near the top of the zone.

No transitional forms or overlap in range were observed between *Globorotalia fohsi barisanensis* and the younger *G. fohsi fohsi*. Compared with Trinidad it appears that in Bodjonegoro-1 only the lower part of the *Globorotalia fohsi barisanensis* zone is present.

Globorotalia fohsi fohsi zone (1705–1842 m)

Globorotalia fohsi fohsi is found throughout this interval. Several other species make their first appearance. One of them is *Globorotalia mohleri* n. sp. It appears at the base of the zone, together with *G. fohsi fohsi*, and continues into the overlying *G. fohsi lobata* zone, where it disappears again. Other characteristic species that appear in the *G. fohsi fohsi* zone are *Sphaeroidinella grimsdalei*, *Globigerina foliata*, *Globoquadrina dehiscens* and *Globorotalia menardii praemenardii*.

Globorotalia fohsi lobata zone (1655–1705 m)

Globorotalia fohsi lobata is the intermediate form between the older *G. fohsi fohsi* and the younger *G. fohsi robusta*. As in Trinidad its range is rather short and the

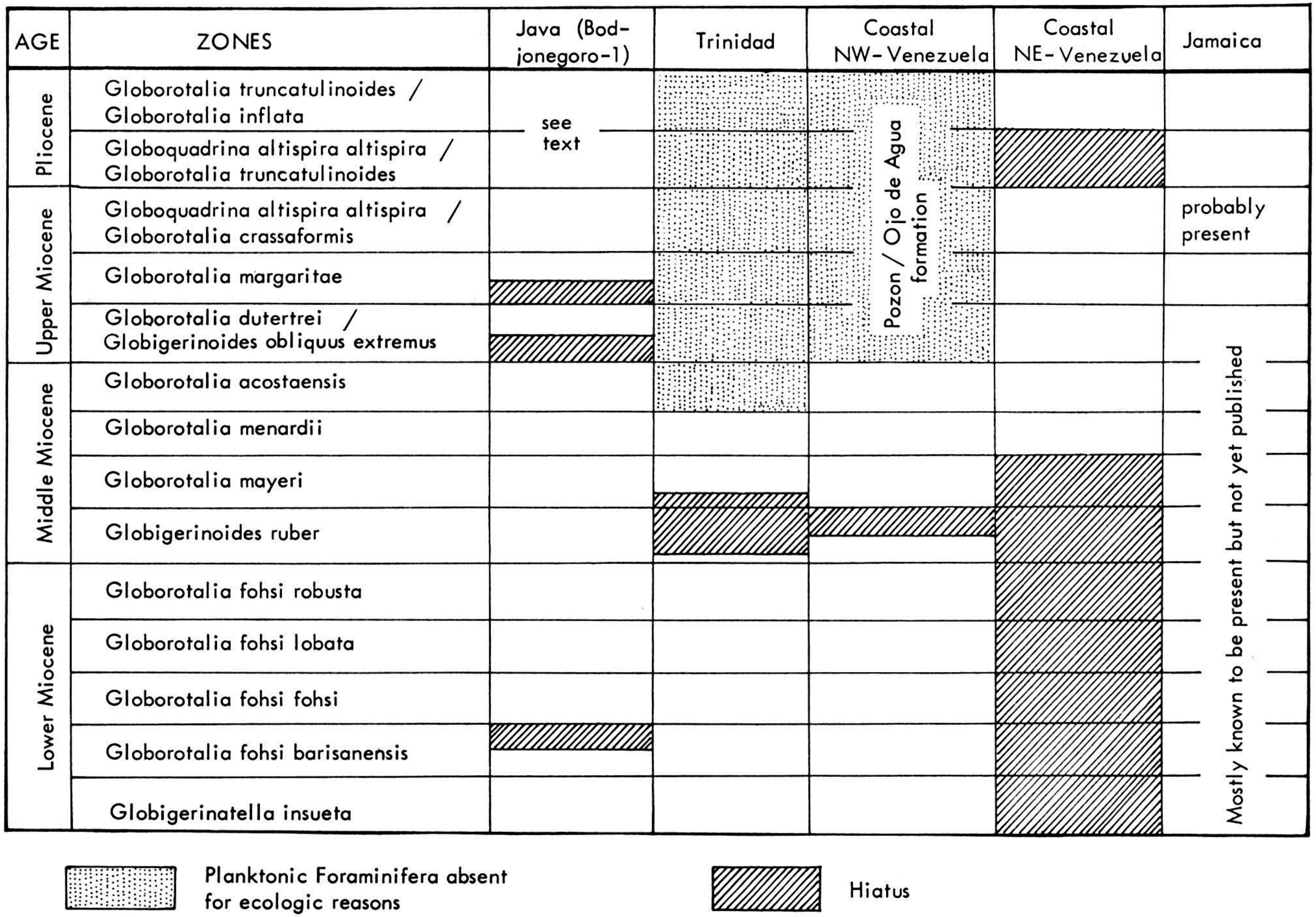


Fig. 1. Lower Miocene to Pliocene planktonic foraminiferal zones in well Bodjonegoro-1, Java and the Caribbean area.

zone therefore of reduced thickness. *G. cf. scitula* appears in the middle part of the zone.

Globorotalia fohsi robusta zone (1431–1655 m)

Globorotalia fohsi robusta occurs throughout the zone, though usually much less frequently than in the Cipero formation of Trinidad.

Globigerinoides ruber zone (1213–1431 m)

As pointed out by Bolli (1964, p. 550), *Globigerinoides ruber* is a species that appears in Trinidad at the base of the *Catapsydrax dissimilis* zone and disappears almost immediately above the top of the *Globorotalia fohsi robusta* zone. Only very occasional specimens persist into the *Globorotalia mayeri* zone of the Lengua formation. The same species, or a form very close to it, reappears in the late Miocene, where it is seen again in the Melajo clays of northern Trinidad.

Blow (1959) shows *Globigerinoides ruber* to continue in eastern Falcón, Venezuela, into the lower part of the *Globorotalia mayeri* zone, to become scarce there, but to reappear again in larger numbers in his *Sphaeroidinella seminulina* and *Globigerina bulloides* zones.

The second appearance of *Globigerinoides ruber* occurs in the Cubagua formation of coastal north-eastern Venezuela at about the base of the *Globorotalia margaritae* zone or already in the uppermost part of the underlying *Globorotalia dutertrei*/*Globigerinoides obliquus extremus* zone.

Globigerinoides ruber continues in Bodjonegoro-1 in considerable numbers for over 200 m (from 1431 to 1213 m) above the extinction level of *Globorotalia fohsi robusta*. The species reappears again at 314 m, in the higher part of the *Globorotalia margaritae* zone. This is somewhat higher stratigraphically than in the Cubagua formation of coastal north-eastern Venezuela (see above). In fig. 1 of Bolli (1964) the levels of the second occurrences of *Globigerinoides ruber* are shown to coincide in Java and Venezuela. Based on further investigations and on the new zones proposed by Bolli & Bermudez (1965) the species reappears in Java a little later, that is only in the higher part of the range of *Globorotalia margaritae* and also above the early sinistrally and random coiling *Pulleniatina obliquiloculata*.

Cassigerinella chipolensis is another species that was found to disappear in Trinidad with *Globorotalia fohsi robusta*. It continues in Bodjonegoro-1 not only as far as *Globigerinoides ruber* but goes on from there for a further 300 m to 918 m, i.e. nearly to the top of the *Globorotalia mayeri* zone at 855 m. This extended range of *Cassigerinella chipolensis* in Java, well into the *Globorotalia mayeri* zone, is a further indication that a hiatus of considerable extent has to be placed between the top of Trinidad's Cipero formation (*Globorotalia fohsi robusta* zone) and the base of the overlying Lengua formation (*Globorotalia mayeri* zone). Compared with the Bodjonegoro-1 section the entire *Globigerinoides ruber* zone of 218 m and the lower part of the *Globorotalia mayeri* zone (295 m) would thus be missing in Trinidad.

The zonal marker *Globigerinoides ruber* is, like *Globorotalia mayeri*, a long ranging species. The base of the zone is determined by the extinction of *Globorotalia fohsi robusta*, the top by the temporary disappearance of *Globigerinoides ruber*.

Globorotalia mayeri zone (855–1213 m)

The zonal marker becomes extinct at the top of the zone, *Cassigerinella chipolensis* and *Globigerinoides altiapertura* disappear in its upper part. *Globorotalia lenguaensis* and *G. pseudomiocenica* appear at the base, *Globorotaloides variabilis*, *Globigerinoides obliquus obliquus* and *Hastigerina aequilateralis* within the zone.

Globorotalia menardii zone (641–855 m)

The zone is characterized by the presence of the zonal marker, *Globorotalia lenguaensis*, *Globigerinita naparimaensis*, etc. *Globoquadrina dehiscens* disappears at the top of the zone.

Globorotalia acostaensis zone (386–641 m)

The first appearance of the zonal marker characterises the base of the zone, the top is marked by the first *Globorotalia dutertrei* and *Globigerinoides obliquus extremus*. The only *Globigerina nepenthes* specimens seen in the Bodjonegoro-1 section occur in this zone. *Globorotalia lenguaensis* disappears in the lower part of the zone, while some *Sphaeroidinella seminulina* and extremely scarce *Globigerinoides ruber* are present in the upper part. *Globorotalia* cf. *scitula* becomes extinct at the top of the zone, *Sphaeroidinella grimsdalei*, *Globorotaloides variabilis* and the zonal marker continue for only a few metres above the top.

A rapid and marked change in the composition of the planktonic foraminiferal fauna takes place between 386 and 305 m. This faunal break is the result of the appearance within this short interval of 15 species and subspecies and the disappearance of 10 species or subspecies.

The faunal change is so abrupt that condensed sedimentation or one or more stratigraphic breaks are thought to be the cause of it. Such an assumption is further substantiated when comparing some species ranges of this particular stratigraphic interval of Bodjonegoro-1 with those of a similar or identical one of well Cubagua-1 in Venezuela. While, for example, *Globorotalia dutertrei* and *G. tumida* cf. *plesiotumida* appear simultaneously in Bodjonegoro-1, *G. tumida* cf. *plesiotumida* appears first about 800 feet (260 m) above the base of *G. dutertrei* in Cubagua-1. Further, *Pulleniatina obliquiloculata* occurs in Bodjonegoro-1 already about 55 feet (18 m) above the *Globorotalia dutertrei*/*G. tumida plesiotumida* base; in Cubagua-1, on the other hand, it occurs about 1300 feet above compared with *Globorotalia dutertrei* and 500 feet above compared with *Globorotalia tumida plesiotumida*.

If possible environmental influences are not taken into account one may conclude from this that in the upper part of the Bodjonegoro-1 section some of the ranges of planktonic Foraminifera are reduced by stratigraphic breaks and/or condensation. Reference is made in this respect also to BOLLI (1964) who compares the ranges of a number of selected planktonic species in Bodjonegoro-1 and Cubagua-1 and points out certain discrepancies.

The zones above the *Globorotalia menardii* zone, including the already listed *Globorotalia acostaensis* zone, were established and defined by BOLLI & BERMUDEZ (1965). They are largely based on the distribution of planktonic Foraminifera in Caribbean sections and also in Bodjonegoro-1. As pointed out above and already mentioned in BOLLI & BERMUDEZ (1965) some of these younger zones are much reduced in thickness in Bodjonegoro-1 as compared with their equivalents in the Caribbean. Further, the two highest zones established in the Caribbean by BERMUDEZ & BOLLI (1965), the *Globoquadrina altispira altispira/Globorotalia truncatulinoides* zone and the *Globorotalia truncatulinoides/Globorotalia inflata* zone, are not recognisable in Bodjonegoro-1. The reasons for this, also discussed by BOLLI & BERMUDEZ (1965), are thought to lie in a warmer water environment for Bodjonegoro-1, being unfavourable for the moderately warm to colder water zonal markers *Globorotalia truncatulinoides* and *G. inflata* that were able to exist in the probably slightly cooler southern Caribbean.

Globorotalia dutertrei/Globigerinoides obliquus extremus zone (354–386 m)

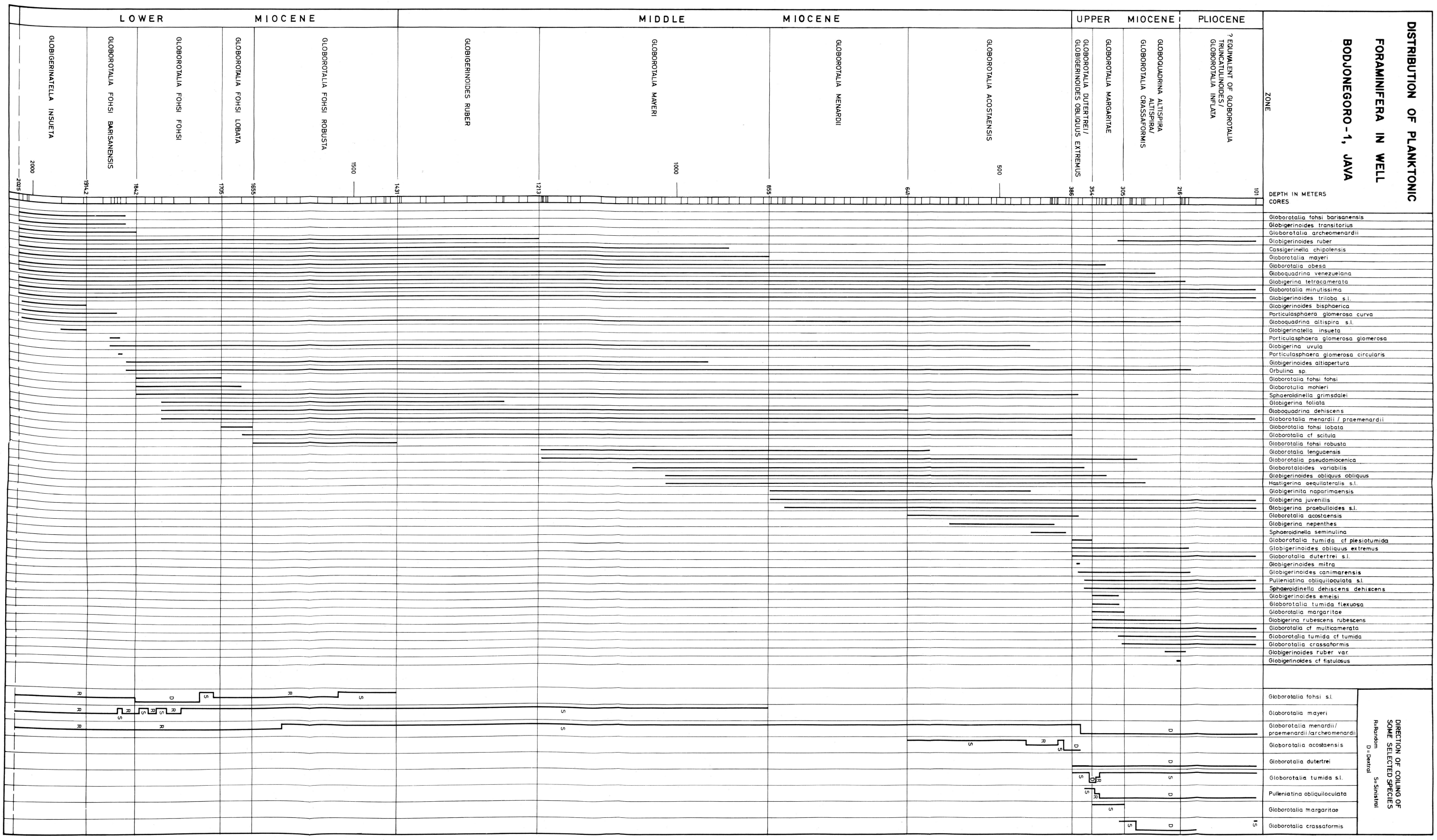
This zone is much reduced in thickness. For reasons discussed above and also by BOLLI & BERMUDEZ (1965) it is thought that the lower part of it is missing. A hiatus of some degree would have to be placed at its base, where *Globigerinoides obliquus extremus, Globorotalia dutertrei* and *Globorotalia tumida* cf. *plesiotumida* appear simultaneously. This is in contrast to Cubagua-1 where these species appear one after the other over an interval of about 1100 feet. The zone is characterised by the zonal markers, *Globorotalia tumida* cf. *plesiotumida* and in the middle to upper part by the newly appearing *Globigerinoides canimarensis*, sinistrally coiling *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens. Globorotaloides variabilis* and *Sphaeroidinella grimsdalei* s.l. disappear in the lower part of the zone.

Globorotalia margaritae zone (305–354 m)

The sudden appearance at the base of this zone of the highly evolved *Globorotalia tumida flexuosa*, without any transitional forms that would link it to the possible ancestor *Globorotalia tumida* aff. *plesiotumida*, indicates that a further hiatus or very strong condensation has most likely to be assumed at the base of the *Globorotalia margaritae* zone. In Bodjonegoro-1 the zone is also much reduced in thickness (49 m) compared with that for example in Cubagua-1 of Venezuela (586 feet or approximately 200 m). *Globorotalia tumida flexuosa* and the new species *Globigerinoides emeisi* occur almost throughout the zone. *Globorotalia tumida* cf. *tumida, G. crassaformis* and *Globigerinoides ruber* (second appearance) come in near the top. The zone is defined by the range of *Globorotalia margaritae.*

Globoquadrina altispira altispira/Globorotalia crassaformis zone (216–305 m)

This interval, taken in Bodjonegoro-1 from the extinction point of *Globorotalia margaritae* to the extinction of *Globoquadrina altispira altispira,* may include in its upper part also the *Globoquadrina altispira altispira/Globorotalia truncatulinoides* zone of the Caribbean. Because of the absence of *Globorotalia truncatulinoides* in Bodjonegoro-1 it is, as already pointed out by BOLLI & BERMUDEZ (1965), not possible to separate these two zones. The thickness of the *Globoquadrina altispira altispira/Globorotalia crassaformis* zone of Bodjonegoro-1 is, like the previous ones, also reduced when compared with those known from the Caribbean. Several species disappear within the zone or just above, some because they apparently become extinct, others probably because of changes in environment.


DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN WELL BODJONEGORO-1, JAVA
LOWER MIOCENE
MIDDLE MIOCENE
UPPER MIOCENE
PLIOCENE
ZONE
GLOBIGERINATELLA INSUETA
GLOBOROTALIA FOHSI BARISANENSIS
GLOBOROTALIA FOHSI FOHSI
GLOBOROTALIA FOHSI LOBATA
GLOBOROTALIA FOHSI ROBUSTA
GLOBIGERINOIDES RUBER
GLOBOROTALIA MAYERI
GLOBOROTALIA MENARDII
GLOBOROTALIA ACOSTAENSIS
GLOBOROTALIA DUTERTREI / GLOBIGERINOIDES OBLIQUUS EXTREMUS
GLOBOROTALIA MARGARITAE
GLOBOQUADRINA ALTISPIRA ALTISPIRA / GLOBOROTALIA CRASSAFORMIS
? EQUIVALENT OF GLOBOROTALIA TRUNCATULINOIDES / GLOBOROTALIA INFLATA
DEPTH IN METERS
CORES
2025
2000
1914.2
1842
1705
1655
1500
1431
1213
1000
855
640
500
386
354
305
216
101
Globorotalia fohsi barisanensis
Globigerinoides transitorius
Globorotalia archeomenardii
Globigerinoides ruber
Cassigerinella chipolensis
Globorotalia mayeri
Globorotalia obesa
Globoquadrina venezuelana
Globigerina tetracamerata
Globorotalia minutissima
Globigerinoides triloba s.l.
Globigerinoides bisphaerica
Porticulasphaera glomerosa curva
Globoquadrina altispira s.l.
Globigerinatella insueta
Porticulasphaera glomerosa glomerosa
Globigerina uvula
Porticulasphaera glomerosa circularis
Globigerinoides altiapertura
Orbulina sp.
Globorotalia fohsi fohsi
Globorotalia mahleri
Sphaeroidinella grimsdalei
Globigerina foliata
Globoquadrina dehiscens
Globorotalia menardii / praemenardii
Globorotalia fohsi lobata
Globorotalia cf scitula
Globorotalia fohsi robusta
Globorotalia lenguaensis
Globorotalia pseudomiocenica
Globorotaloides variabilis
Globigerinoides obliquus obliquus
Hastigerina aequilateralis s.l.
Globigerinita naparimaensis
Globigerina juvenilis
Globigerina praebulloides s.l.
Globorotalia acostaensis
Globigerina nepenthes
Sphaeroidinella seminulina
Globorotalia tumida cf plesiotumida
Globigerinoides obliquus extremus
Globorotalia dutertrei s.l.
Globigerinoides mitra
Globigerinoides conimarensis
Pulleniatina obliquiloculata s.l.
Sphaeroidinella dehiscens dehiscens
Globigerinoides emeisi
Globorotalia tumida flexuosa
Globorotalia margaritae
Globigerina rubescens rubescens
Globorotalia cf multicamerata
Globorotalia tumida cf tumida
Globorotalia crassaformis
Globigerinoides ruber var.
Globigerinoides cf fistulosus
Globorotalia fohsi s.l.
Globorotalia mayeri
Globorotalia menardii / praemenardii / archeomenardii
Globorotalia acostaensis
Globorotalia dutertrei
Globorotalia tumida s.l.
Pulleniatina obliquiloculata
Globorotalia margaritae
Globorotalia crassaformis
DIRECTION OF COILING OF SOME SELECTED SPECIES
R=Random S=Sinistral
D=Dextral

?Equivalent of the *Globorotalia truncatulinoides/Globorotalia inflata* zone (214–101m)

Cores from only the bottom part and the top of this interval were available. A certain impoverishment in the planktonic foraminiferal fauna, in particular in the core at 101 m, is noted. Forming the immediate continuation above the extinction of *Globoquadrina altispira altispira*, it is possible that this interval represents the stratigraphic warm water equivalent of the *Globorotalia truncatulinoides/Globorotalia inflata* zone of the Caribbean (BOLLI & BERMUDEZ, 1965).

THE DIRECTION OF COILING OF SOME SELECTED SPECIES

The directions of coiling of nine selected species are shown in table 1. The change to dextral coiling after a short initial sinistral stage in *Pulleniatina obliquiloculata* has already been discussed by BOLLI (1964). Also discussed in the same note were the coiling patterns of *Globorotalia menardii* s.l., *G. tumida* s.l., and *G. dutertrei*. The following notes refer to the additional species shown in table 1.

a) *Globorotalia fohsi* s.l.

This species with its subspecies follows in Bodjonegoro-1 a different coiling pattern to that found in Trinidad (BOLLI, 1950). There, the early forms of *Globorotalia fohsi barisanensis* coil at random, changing later to a distinct preference for sinistral coiling which is maintained throughout the ranges of the younger *G. fohsi fohsi*, *G. fohsi lobata* and *G. fohsi robusta*.
The picture is a much more irregular one in Bodjonegoro-1. Here, *Globorotalia fohsi barisanensis* coils at random throughout the *Globigerinatella insueta* zone and the *Globorotalia fohsi barisanensis* zone of which the upper part is probably missing. *G. fohsi fohsi* coils dextrally throughout most of its range, to switch to sinistral coiling only in the upper part of the zone. *G. fohsi lobata* and most of the *G. fohsi robusta*, which are scarce, appear to have no preferred direction of coiling. Only in the upper part of the *G. fohsi robusta* zone does the zonal marker seem to develop a preference again for sinistral coiling.
Such difference in the pattern of the direction of coiling during the range of the *Globorotalia fohsi* subspecies, in Trinidad on one side and Java on the other, indicate that they should be used with care for correlations over wide distances.

b) *Globorotalia mayeri*

Globorotalia mayeri coils at random in the *Globigerinatella insueta* and in the lower part of the *Globorotalia fohsi barisanensis* zones. It begins to develop sporadic preferences for sinistral coiling in the upper part of the *G. fohsi barisanensis* and the lower part of the *G. fohsi fohsi* zones, to become sinistrally coiling from the upper part of the *G. fohsi fohsi* zone to the point of extinction at the top of the *G. mayeri* zone. A similar coiling pattern was also observed for this species in Trinidad.

c) *Globorotalia acostaensis*

The species coils sinistrally throughout the lower and middle part of the *Globorotalia acostaensis* zone becoming random and then, for a short interval, sinistral again in the upper part. Near the top of the zone the species switches to dextral coiling.

d) *Globorotalia margaritae*

The species coils sinistrally throughout the observed range; the same coiling direction also persists in the Caribbean area.

e) *Globorotalia crassaformis*

Early specimens coil sinistrally, but the species soon changes to dextral coiling for most of the observed range. Only the youngest specimens in the top core prefer sinistral coiling again, the same direction that strongly prevails in the living representatives of the species. *Globorotalia crassaformis* prefers sinistral coiling throughout its observed range in Cubagua-1, Venezuela.

PERCENTAGES OF PLANKTONIC AND BENTHONIC FORAMINIFERA

The planktonic Foraminifera strongly dominate numerically the benthonic forms in practically all of the 149 examined core samples throughout the Bodjonegoro-1 section. The following summarised figures not only show this distinct dominance but also the fluctuations of the percentage ratios that characterise different intervals of the section.

Depth in metres	% planktonic	% benthonic
101	75	25
204– 434	90–98	2–10
(at 295	50	50)
451– 631	60	40
641–1043	40–60	40–60
1060–1443	60–70	30–40
1451–1675	90–95	5–10
1705–2025	60–70	30–40
(at 1891	10	90)

THE PLANKTONIC FORAMINIFERA IN THE WELL SECTION

The following 56 alphabetically arranged planktonic foraminiferal species and subspecies are present in Bodjonegoro-1. Representative specimens of each species and subspecies are deposited at the Museum of Natural History, Basel. The corresponding Museum numbers are indicated on the following list (C 24477–C 24536). The stratigraphic distribution in the section is shown in table 1.

Cassigerinella chipolensis (CUSHMAN & PONTON). C 24477

Globigerina *foliata* BOLLI, C 24478
juvenilis BOLLI, C 24479
nepenthes TODD, C 24480
praebulloides s.l. BLOW, C 24481
rubescens rubescens HOFKER, C 24482
uvula EHRENBERG, C 24483
tetracamerata BOLLI & BERMUDEZ, C 24484

Globigerinatella insueta CUSHMAN & STAINFORTH, C 24485

Globigerinita naparimaensis BRÖNNIMANN, C 24486

Globigerinoides altiapertura BOLLI, C 24487
bisphaerica TODD, C 24488
canimarensis BERMUDEZ, C 24489
emeisi BOLLI, C 24490, 91
cf. *fistulosus* (SCHUBERT), C 24492, 93
mitra TODD, C 24494
obliquus extremus BOLLI & BERMUDEZ, C 24495,96
obliquus obliquus BOLLI, C 24497
ruber (D'ORBIGNY), C 24498
ruber (D'ORBIGNY) var., C 24499, 24500
transitorius BLOW, C 24501
triloba s.l. (REUSS), C 24502

Globoquadrina altispira s.l. (CUSHMAN & JARVIS), C 24503
dehiscens (CHAPMAN, PARR & COLLINS), C 24504
venezuelana (HEDBERG), C 24505

Globorotalia acostaensis BLOW, C 24506
archaeomenardii BOLLI, C 24507
crassaformis (GALLOWAY & WISSLER), C 24508
dutertrei s.l. (D'ORBIGNY), C 24509
fohsi barisanensis LEROY, C 24510
fohsi fohsi CUSHMAN & ELLISOR, C 24511
fohsi lobata BERMUDEZ, C 24512
fohsi robusta BOLLI, C 24513
lenguaensis BOLLI, C 24514
margaritae BOLLI & BERMUDEZ, C 24515
mayeri CUSHMAN & ELLISOR, C 24516
menardii (D'ORBIGNY)/*praemenardii* CUSHMAN & STAINFORTH, C 24517
minutissima BOLLI, C 24518
mohleri BOLLI, C 24519
cf. *multicamerata* CUSHMAN & JARVIS, C 24520
obesa BOLLI, C 24521
pseudomiocenica BOLLI & BERMUDEZ, C 24522
cf. *scitula* (BRADY), C 24523
tumida flexuosa (KOCH), C 24524
tumida cf. *plesiotumida* BANNER & BLOW, C 24525
tumida cf. *tumida* (BRADY), C 24526

Globorotaloides variabilis BOLLI, C 24527

Hastigerina aequilateralis s.l. (BRADY), C 24528

Orbulina s.l. D'ORBIGNY, C 24529

Porticulasphaera glomerosa circularis (BLOW), C 24530
glomerosa curva (BLOW), C 24531
glomerosa glomerosa (BLOW), C 24532

Pulleniatina obliquiloculata s.l. (PARKER & JONES), C 24533

Sphaeroidinella dehiscens dehiscens (PARKER & JONES), C 24534
grimsdalei (KEIJZER), C 24535
seminulina (SCHWAGER), C 24536

Of these, the following two species are described as new:

Globigerinoides emeisi, n. sp.

Plate I, figs. 11–14

Shape of test low trochospiral, equatorial periphery distinctly lobate (trilobate to quadrilobate); axial periphery rounded. Wall calcareous, perforate, nearly smooth. Chambers spherical, about 10 arranged in about $2^1/_2$ whorls; the three chambers of the last whorl increase rapidly in size, the last chamber being of nearly the same volume as all the previous ones together. Sutures on spiral and umbilical side radial, distinctly incised. Primary aperture of last chamber very large, wider than high, interiomarginal, umbilical; the single supplementary aperture of the last chamber of similar proportions but smaller in size than the primary aperture. The supplementary chamber of the penultimate chamber is visible on the holotype. Largest diameter of holotype: 0.6 mm.

Stratigraphic range (in the Bodjonegoro-1 section): *Globorotalia margaritae* zone, Upper Miocene or ?Pliocene, Kalibeng beds.

Locality: Holotype (pl. 1, figs. 11–13) and figured paratype (pl. 1, fig. 14) from core 347 m of B.P.M. well Bodjonegoro-1. Geol. map of Java, sheet 104A, coord. S 12000 m, E 5700 m from the NW corner of map. About 90 km W of Surabaia, Java. The figured specimens are deposited in the Museum of Natural History, Basel (holotype C 24490, paratype C 24491).

Remarks: Globigerinoides emeisi, n. sp., is distinguished from *Globigerinoides triloba immatura* LE ROY by possessing a distinctly larger, higher and wider primary aperture. From *Globigerinoides altiapertura* BOLLI it differs in the much wider primary and supplementary apertures of the last chamber. A specimen of *Globigerinoides altiapertura* from the type locality in Trinidad is figured in plate 1, figs. 1 and 2 for comparison of its apertures with those of *Globigerinoides emeisi* (plate 1, figs. 13 and 14). *Globigerinoides emeisi* differs from *Globigerinoides obliquus obliquus* (plate 1, figs. 18 and 19) in the more globular and not obliquely compressed final chamber.

Globigerinoides emeisi is restricted to the *Globorotalia margaritae* zone in Bodjonegoro-1. *Globigerinoides altiapertura* ranges in this section from the uppermost part of the *Globorotalia fohsi barisanensis* zone into the *Globorotalia mayeri* zone, while *Globigerinoides triloba immatura* occurs throughout the examined section, i.e. from the *Globigerinatella insueta* zone to the *Globoquadrina altispira altispira/Globorotalia crassaformis* zone and higher.

Globigerinoides emeisi has the same short range in Bodjonegoro-1 as *Globorotalia tumida flexuosa* and occurs during an interval where planktonic Foraminifera are very rich and many species reach a considerable size. This indicates extremely favourable living conditions under which the new species has developed, probably by branching off from the *Globigerinoides triloba* complex or possibly from *Globigerinoides obliquus* s.l.

The species is named after Dr. J. D. Emeis of the B.I.P.M., The Hague, Holland, who has kindly encouraged this study.

Globorotalia mohleri, n. sp.
Plate I, figs. 3–5

Shape of test very low trochospiral, equatorial periphery slightly lobate; axial periphery rounded. Wall calcareous, finely perforated, surface smooth. Chambers rounded, longer than high seen from the spiral side; about 10–12, arranged in 2–2 $^1/_2$ whorls; the 4 to 4 $^1/_2$ chambers of the last whorl increase moderately in size. Sutures on spiral side oblique, slightly curved and depressed, on umbilical side radial, depressed. Umbilicus very small and narrow. Aperture a narrow, long slit, bordered above by a narrow rim or lip; interiomarginal, umbilical-extraumbilical. Coiling: apparently random. Largest diameter of holotype: 0.18 mm.

Stratigraphic range (in the Bodjonegoro-1 section): *Globorotalia fohsi fohsi* zone to middle part of *Globorotalia fohsi lobata* zone, Middle Miocene, Kalibeng beds or ? Rembang beds.

Locality: Holotype (pl. 1, figs. 3–5) from core interval 1799–1800.5 m of B.P.M. well Bodjonegoro-1. Geol. map of Java, sheet 104A, coord. S 12000 m, E 5700 m from the NW corner of map. About 90 km W of Surabaia, Java. The holotype is deposited in the Museum of Natural History, Basel (C 24519).

Remarks: Globorotalia mohleri, n. sp., is a very small, rounded form with a restricted range in Bodjonegoro-1. It differs from *Globorotalia minutissima* Bolli in possessing only 4–4 $^1/_2$ chambers in the last whorl as compared with 5 in *Globorotalia minutissima* and in having a less lobate equatorial periphery. Furthermore, the stratigraphic range of *Globorotalia mohleri* is much more restricted than that of *Globorotalia minutissima* which ranges in Trinidad from the *Catapsydrax stainforthi* zone to the *Globorotalia menardii* zone.

The species is named after Dr. W. A. Mohler, Gelterkinden, Switzerland, in recognition of his paleontologic and geologic work.

Only a few selected species of the already known planktonic Foraminifera are figured in plate 1. For the others reference is made to the descriptions and illustrations in Bolli (1957a), and also in Bermudez (1961), Bolli & Bermudez (1965), Banner & Blow (1965) and Blow (1959).

A specimen of *Globigerinoides altiapertura* from Trinidad (figs. 1 and 2) and a specimen of *Globigerinoides obliquus obliquus* (figs. 18 and 19) illustrate the differences between these species. A variant of *Globigerinoides ruber* in which the final chamber is similarly compressed as in *Globigerinoides obliquus obliquus* and *G. obliquus extremus* is shown in figs. 6 and 8–10. Such forms were found to be restricted in the Bodjonegoro-1 section to a short interval of about 30 m, ranging from just below to just above the extinction point of *Globoquadrina altispira* s.l. The umbilical view of a *Globigerinoides ruber* with normal end chamber and coming from the interval of second appearance (see *Globigerinoides ruber* zone, p. 8) is given in fig. 7.

A specimen of *Globigerinoides obliquus obliquus* and two specimens of *G. obliquus extremus* are shown in figs. 18, 19 and 17, 20, 21. *Globigerinoides obliquus extremus* is thought to develop from *G. obliquus obliquus* by the chambers becoming still more compressed in an oblique way. The two subspecies overlap in Bodjonegoro-1 in the lower part of the *Globorotalia margaritae* zone. *Globigerinoides obliquus extremus* disappears a few metres above the extinction of *Globoquadrina altispira* s.l. This subspecies has already been noted in Venezuela in the *Globorotalia acostaensis* zone to *Globoquadrina altispira altispira/Globorotalia crassaformis* zone, it is no longer present in the *Globorotalia truncatulinoides/Globorotalia inflata* zone and is also not known from the Recent. It appears to be a useful index fossil for the Upper Miocene and possibly part of the Pliocene.

Two specimens of *Globigerinoides triloba* aff. *fistulosus* (SCHUBERT) are figured. Such forms were only seen in core samples 214 and 216 m, i.e. with the last *Globoquadrina altispira* s.l. The Bodjonegoro-1 specimens differ from the typical *Globigerinoides triloba fistulosus* in having much shorter spines or fistules. This may be the result of damage or erosion. The species was originally described by SCHUBERT from the youngest Pliocene or ?Pleistocene of Siminis on Djaul, Sandwich Island, Bismarck Archipelago. BELFORD (1962) cites and figures such forms from a single sample in New Guinea which he considers to be uppermost Miocene or Pliocene. From this and from the occurrence in Bodjonegoro-1 it appears that *Globigerinoides triloba fistulosus* has quite a short range in the highest Miocene and/or Pliocene.

Stratigraphic breaks and/or condensation at crucial levels of Bodjonegoro-1 seem to prevent the study of a continuous evolutionary sequence of *Globorotalia tumida* s.l. Forms in table 1 referred to as *Globorotalia tumida* cf. *plesiotumida* appear suddenly at 386 m together with *Globorotalia dutertrei* and *Globigerinoides obliquus extremus*. The specimens of Bodjonegoro-1 appear to come from an already slightly higher evolutionary stage than the typical *Globorotalia tumida plesiotumida* from well Cubagua-2, Venezuela, of which Dr. W. H. BLOW kindly furnished some specimens for comparison.

At 354 m the subspecies cf. *plesiotumida* becomes equally suddenly replaced by the highly developed *Globorotalia tumida flexuosa* which goes together with *Globigerinoides emeisi* to 314 m, where it becomes itself replaced by forms only slightly differing from today's *Globorotalia tumida tumida*. These forms, ranging from 314 m to the highest core at 101 m, are plotted in table 1 as *Globorotalia tumida* cf. *tumida*.

Finally, it is noted that *Globigerina nepenthes* is restricted in Bodjonegoro-1 to the *Globorotalia acostaensis* zone where it is scarce and occurs only sporadically. This species begins in Trinidad in the *Globorotalia mayeri* zone and can be followed throughout the *Globorotalia menardii* zone. In well Cubagua-1 of Venezuela the species is present in the deepest recognised zone of the well, i.e. in the *Globorotalia acostaensis* zone, to disappear in the middle part of the overlying *Globorotalia dutertrei/Globigerinoides obliquus extremus* zone.

The absence of *Globigerina nepenthes* in the *Globorotalia mayeri* and *Globorotalia menardii* zones and its scarcity in the *Globorotalia acostaensis* zone of Bodjonegoro-1 is an indication that the distribution of the species must have been controlled by certain restricted, still unknown ecological conditions within the tropical to subtropical open marine seas. Its value as an index fossil even within apparently favourable environments is therefore questioned.

RÉSUMÉ

Foré en 1934 et situé environ 90 km à l'Ouest de Surabaia en Java, le sondage de Bodjonegoro-1 a traversé 2025 m de couches marines dites de Kalibeng et de Rembang qui représentent le Néogène depuis le Miocène inférieur au Pliocène. La plus grande partie de la section forée est représentée par des carottes de sondages qui sont généralement très riches en foraminifères planctoniques. Cependant, des formes benthoniques et d'autres microfossiles n'y manquent pas. Une première étude des foraminifères de ce sondage fut publiée en 1949 par Boomgart, mais depuis cette époque l'on connait mieux les foraminifères planctoniques et beaucoup de leurs espèces sont utilisées aujourd'hui avec succès pour la zonation et la corrélation des séries sédimentaires néogènes.

Une coupe aussi complète et aussi riche en foraminifères planctoniques allant du Miocène inférieur au Pliocène sans montrer d'apparentes lacunes ne semble pas avoir été découvert jusqu'ici. C'est pourquoi le matériel du sondage Bodjonegoro-1 fournit une occasion unique d'étudier les foraminifères planctoniques à la lumière des connaissances actuelles. En même temps, il est particulièrement intéressant de comparer la composition faunistique et la répartition stratigraphique des espèces dans une province tropicale du Pacifique avec celles des Caraïbes où la plupart des espèces ont été décrites. Dans ce travail, la zonation basée sur les foraminifères planctoniques et établie dans les Caraïbes est appliquée la première fois à une coupe complète allant du Miocène inférieur au Pliocène dans l'Indonésie.

Au fond du sondage Bodjonegoro-1, la zone à *Globigerinatella insueta* peut être mise en évidence. Toutes les zones que l'on distingue à la Trinité entre cell-ci et la zone à *Globorotalia menardii*, peuvent être reconnues dans la coupe de ce sondage. En outre, une zone supplémentaire dite à *Globigerinoides ruber* est proposée ici. Elle se situerait entre la zone à *Globorotalia fohsi robusta* et la zone à *Globorotalia mayeri*. Situées au-dessus de la zone à *Globorotalia menardii*, les zones à *Globorotalia acostaensis* jusqu'à la zone à *Globoquadrina altispira altispira/Globorotalia crassaformis* instituées récemment par Bolli & Bermudez (1965) peuvent être observées également dans ce sondage. Cependant, les zones les plus récentes de ces deux

auteurs, la zone à *Globoquadrina altispira altispira/Globorotalia truncatulinoides* et la zone à *Globorotalia truncatulinoides/Globorotalia inflata*, ne peuvent être séparées dans la coupe de Bodjonegoro-1, les conditions écologiques étant probablement différentes.

Cinquante-six espèces et sous-espèces de foraminifères planctoniques ont été déterminées dans la coupe du sondage de Bodjonegoro-1. Leur répartition stratigraphique est donnée dans le tableau 1. *Globigerinoides emeisi* et *Globorotalia mohleri* sont proposés ici comme espèces nouvelles. Les directions d'enroulement de quelques espèces choisies sont brièvement discutées et leurs pourcentages sont indiqués dans le tableau 1.

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Plate I

Figs. 1–2 *Globigerinoides altiapertura*. 1: spiral view. 2: umbilical view. Paratype from the *Catapsydrax dissimilis* zone, Cipero formation, Trinidad. For comparison with other *Globigerinoides* species figured on Plate I. × 110. C 24476.

Figs. 3–5 *Globorotalia mohleri* n. sp., holotype. 3: umbilical view. 4: spiral view. 5: side view. From the *Globorotalia fohsi fohsi* zone, Bodjonegoro-1, core 1799–1800 m. × 168. C 24519.

Fig. 6 *Globigerinoides ruber* var. Umbilical view. From Bodjonegoro-1, core 210 m. × 82. C 24499.

Fig. 7 *Globigerinoides ruber*. Umbilical view. From Bodjonegoro-1, core 210 m. × 74. C 24498.

Figs. 8–10 *Globigerinoides ruber* var. 8: side view. 9: side view. 10: umbilical view. From Bodjonegoro-1, core 216 m. × 78. C 24500.

Figs. 11–13 *Globigerinoides emeisi* n. sp., holotype. 11: umbilical view. 12: side view. 13: spira-view. From the *Globorotalia margaritae* zone, Bodjonegoro-1, core 347 m. × 50. C 24490.

Fig. 14 *Globigerinoides emeisi* n. sp., paratype. Umbilical view. From the *Globorotalia margaritae* zone, Bodjonegoro-1, core 347 m. × 56. C 24491.

Fig. 15 *Globigerinoides* cf. *fistulosus*. Spiral view. From Bodjonegoro-1, core 214 m. × 46. C 24492.

Fig. 16 *Globigerinoides* cf. *fistulosus*. Spiral view. From Bodjonegoro-1, core 216 m. × 46. C 24493.

Fig. 17 *Globigerinoides obliquus extremus*. Umbilical view. From Bodjonegoro-1, core 314 m. × 74. C 24496.

Figs. 18–19 *Globigerinoides obliquus obliquus*. 18: spiral view. 19: umbilical view. From the *Globorotalia acostaensis* zone, Bodjonegoro-1, core 464 m. × 82. C 24497.

Figs. 20–21 *Globigerinoides obliquus extremus*. 20: spiral view. 21: umbilical view. From the *Globorotalia margaritae* zone, Bodjonegoro-1, core 314 m. × 52. C 24495.

All figured specimens are deposited at the Museum of Natural History, Basel (C 24476 etc.).


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