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Autor(en): **Bolli, H.M.**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **57 (1964)**

Heft 2

PDF erstellt am: **26.04.2024**

Persistenter Link: https://doi.org/10.5169/seals-163150

Observations on the Stratigraphic Distribution of Some Warm Water Planktonic Foraminifera in the Young Miocene to Recent

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With 1 figure in the text

INTRODUCTION

The stratigraphic distribution and coiling patterns of a number of selected warm water planktonic foraminiferal species are discussed, as observed in some geographically widely separated sections of young Miocene to Recent age. In comparing ranges between these sections some apparent discrepancies came to light. Not until these, and those of probably other species, are satisfactorily resolved will it be possible to establish the maximum stratigraphic range of each of these planktonic species. Based on the complete ranges, a world-wide zonation of the tropical Miocene to Recent marine sediments could then be prepared, similar to that already established for the older Miocene and the earlier Tertiary. In Trinidad, W.I. (lat. 10–11° N; long. 61–62° W) such a zonation was worked out throughout the Tertiary as high as the Middle Miocene *Globorotalia menardii* zone, Lengua formation (Bolli 1959). Conditions there for planktonic Foraminifera became unfavourable in the higher Miocene and younger sediments, and suitable sections had thus to be found outside Trinidad.

A first step in this direction was made by Blow (1959), who investigated the planktonic Foraminifera of the Pozón formation of eastern Falcón, Venezuela (lat. 11° N; long. 69° W). Though the planktonic Foraminifera continue there into higher strata than is the case in Trinidad, they also begin to disappear already well below the Miocene/Pliocene boundary, due to an apparent progressive shallowing of the sea.

Bandy (1962, 1963a, 1963b, 1964) has recently published several papers on the distribution of planktonic Foraminifera from Miocene to Recent and their use for stratigraphy. His own observations are based largely on a number of surface and subsurface sections in the Philippines (Luzon and Panay islands, lat. 10–19° N; long. 120–124° E). There he applies the European stages Aquitanian to Pontian for the subdivision of the Miocene and places the ranges of the predominantly tropical planktonic foraminiferal species within these stage limits. Such an attempt to equate the distribution of tropical planktonic Foraminifera with European Miocene stages seems to the writer, at least in part, still somewhat premature. Tropical Miocene planktonic index Foraminifera such as have been described, for instance, from Trinidad, W.I. and Falcón, Venezuela, have so far in Europe only been recognised in the Oligocene and in the older Miocene. Marker species younger than *Globigerinatella insueta* and *Globorotalia fohsi barisanensis*, such as *Globorotalia fohsi fohsi*, *G. fohsi lobata*, *G. fohsi robusta*, etc. have, to the writer's knowledge, not been reported from European Miocene stages. In their place there seem to be present species of a colder water environment with, as one example, *Globigerina bulloides* s.l. often common. Further, in some of the stage type localities, such as the Helvetian, no planktonic Foraminifera at all are present. A direct correlation of the tropical young Miocene planktonic Foraminifera with European stages remains, therefore, to a large extent problematical (see Bolli in Drooger 1964).

Another recent publication on tropical Miocene and Pliocene planktonic Foraminifera is that by Belford (1962) who describes and figures the faunas from Papua and New Guinea (lat. 0–10° S, long. 130–150° E). The author states that only few of the samples available for his study were collected in stratigraphic sequence. For this reason he can say little on the vertical ranges of the recorded species and his paper is therefore of little help in the present discussion.

Jenkins (1964), in addition to discussing the Pliocene/Pleistocene boundary in New Zealand (east coast of North Island, lat. 38–42° S; long. 176–178° E), Italy (Calabria, lat. 38–40° N; long. 16–17° E) and California (Los Angeles area, lat. 34° N; long. 118° W), gives a chart showing the distribution of planktonic Foraminifera in the Upper Miocene, Pliocene and Pleistocene of New Zealand. His areas are already outside the belt of typical tropical planktonic Foraminifera, as is shown by the absence of such species as *Globorotalia menardii* in the Pliocene/Pleistocene sections of Italy and California. In New Zealand this species disappears within the Pliocene, apparently due to lowering of the water temperature. Being of temperate to subtropical origin, the fauna of the New Zealand Upper Miocene to Pleistocene seems, however, to hold an important key position for an eventual correlation of tropical with colder water faunas.

Continuous sections suitable for the study of Upper Miocene, Pliocene and Pleistocene warm water planktonic Foraminifera are apparently not easily obtained. The writer was therefore fortunate to have at his disposal core material of Bodjonegoro well No. 1, drilled in 1934 by the Bataafsche Petroleum Maatschappij north of Bodjonegoro, situated 90 km west of Soerabaja, Java (lat. 8° S; long. 111° E). The well reached a total depth of 2006 metres, penetrating a marine sequence extremely rich in benthonic and especially planktonic Foraminifera which range in age from the Miocene *Globigerinatella insueta* zone into the Pliocene. The section was practically continuously cored and closely spaced samples were thus available to follow the distribution of the planktonic Foraminifera. The fauna of the Bodjonegoro-1 section was previously published by Boomgaart in 1949, but the finer subdivision of Tertiary planktonic Foraminifera was not yet established and many species used today as valuable stratigraphic markers are thus not distinguished in his study.

A second well section available to the author for the study of young Miocene and Pliocene planktonic Foraminifera is that of Cubagua-1, drilled in 1940, for C.A. Yacimientos Petroliferos de Cubagua by Mobil Oil Company de Venezuela (then Socony Vacuum) on the island of Cubagua, off the north coast of Venezuela (lat.

11°N; long. 64°W). Before entering a barren interval of approximately 1200 feet and eventually the Middle Eocene this well penetrated about 3000 feet of Pliocene and Upper Miocene of post *Globorotalia menardii* zone age (post-Lengua formation of Trinidad), again extremely rich in planktonic and benthonic Foraminifera. Similar to Bodjonegoro-1, this section was also very closely cored, thus allowing for a detailed distribution study of the foraminiferal fauna.

Apart from Bandy's publications on the Philippine faunas little is known to date on the relative stratigraphic distribution of Upper Miocene to Recent warm water planktonic Foraminifera. For an eventual standard distribution chart of young Miocene to Recent species it is therefore of importance to compare his results with other sections. The geographically far separated sections of Bodjonegoro-1 in Java and Cubagua-1 on the island of Cubagua in the Caribbean Sea seem to be ideally suited for such a purpose.

It is intended to publish the planktonic Foraminifera and their stratigraphic distribution within the Bodjonegoro-1 section and also the complete foraminiferal fauna of Cubagua-1 *in extenso* in separate papers. In the present note only a number of Upper Miocene to Recent index species are selected to compare their relative ranges as observed with each other and also with those given by Bandy for his Philippine sections.

The actual placing of the Miocene/Pliocene and Pliocene/Pleistocene boundaries based largely on planktonic Foraminifera was recently discussed in several papers (ERICSON *et al.*, 1963; RIEDEL *et al.*, 1963; BANDY, 1963a, 1963b, 1964; JENKINS, 1964). The observations in the present paper would indicate that additional work on a world-wide scale is still needed to arrive at valid conclusions. No further views on the placement of these boundaries are therefore offered here but solely for ease of reference, BANDY's usage for the Miocene/Pliocene boundary is adopted in the remainder of this paper. It should also be noted that the writer places the base of the Upper Miocene at the Tortonian/Sarmatian boundary and does not agree with BANDY's inclusion of the Vindobonian in the Upper Miocene (see also STAINFORTH, 1964).

The author wishes to thank the Bataafsche Internationale Petroleum Maatschappij for giving permission to publish this paper and Dr. R. M. STAINFORTH for reading and discussing the manuscript.

COMPARISON OF SPECIES RANGES IN THE PHILIPPINES, JAVA AND VENEZUELA

The ranges of certain species as recorded in the Philippines by BANDY (1963a, 1963b, 1964) and by the writer in the two wells mentioned above, one in Java and one in Venezuela, are discussed. Figure 1 expresses the data graphically and should be used in conjunction with the text.

While there is good agreement in the ranges of some species between the sections of Java, the Philippines and Cubagua there are others whose stratigraphic distribution seems to vary quite considerably. Such discrepancies may be due to one or more of the following reasons:

(a) Differing ecological conditions, affecting the distribution of certain species.

(b) Parts of sections missing as a result of hiatuses, condensation, tectonic movements.
(c) Differences in the interpretation of a species.

Pulleniatina obliquiloculata (PARKER & JONES)

One of the more interesting species for a stratigraphic correlation between the three areas is *Pulleniatina obliquiloculata*. BANDY (1963a, 1963b, 1964) distinguishes in the Philippines the following four distinct intervals of coiling directions during its range, from bottom to top:

(1) Sinistrally coiling during the Upper Miocene Sarmatian stage, specimens rare.
(2) Dextrally coiling during the Upper Miocene Pontian stage, specimens rare.
(3) Sinistrally coiling for a short interval beginning at the base Pliocene, specimens more frequent.
(4) Dextrally coiling from within Lower Pliocene to Recent, specimens more frequent.

In Bodjonegoro-1 of Java *Pulleniatina obliquiloculata* is present in the upper 800 feet. At the basal 60 feet of this interval specimens are quite plentiful, all coiled sinistrally and associated with *Sphaeroidinella dehiscens dehiscens*. This occurrence apparently corresponds with BANDY's second sinistrally coiling interval, which according to him marks the base of the Pliocene. Above is a short interval of less than 30 feet where the specimens coil at random; with closer sampling such an intermediate stage might also be detected in the Philippines and in Cubagua-1 (Venezuela). Above this point, through the remaining section, the Pulleniatinas coil dextrally.

Cubagua-1 presents a picture similar to Bodjonegoro-1. The early left coiling Pulleniatinas are not scarce and in surface sections of identical stratigraphic position, on the neighbouring Peninsula de Araya they are even abundant. But while the dextrally coiling Pulleniatinas continue to the top of the section in Bodjonegoro-1, the species disappears in Cubagua-1 shortly after it becomes dextrally coiling. This disappearance was likely caused by an ecological change.

In the Upper Pliocene-?Pleistocene Cumaná beds of Cumaná and in the Playa Grande formation of the Cabo Blanco Group, both situated along the north coast of Venezuela, as well as in today's Caribbean Sea, dextrally coiling *Pulleniatina obliquiloculata* are present again.

The quantitative use of a species for stratigraphic correlation may, in restricted areas, be reliable. Over long distances, however, such as are involved in this paper, the abundance factor has to be used with great care because frequencies of specimens may vary with only slight changes in their habitats.

When taking the base of BANDY's higher, sinistrally coiling and more frequent Pulleniatinas as a datum and correlating it with the base of the only sinistrally coiling *Pulleniatina* intervals of Bodjonegoro-1 and Cubagua-1, one finds good agreement with the base of *Sphaeroidinella dehiscens dehiscens* between the Philippines and Java. Further, the comparable stratigraphic position of the top of *Globigerina nepenthes* appears to fall in line in the three areas. On figure 1 the base of

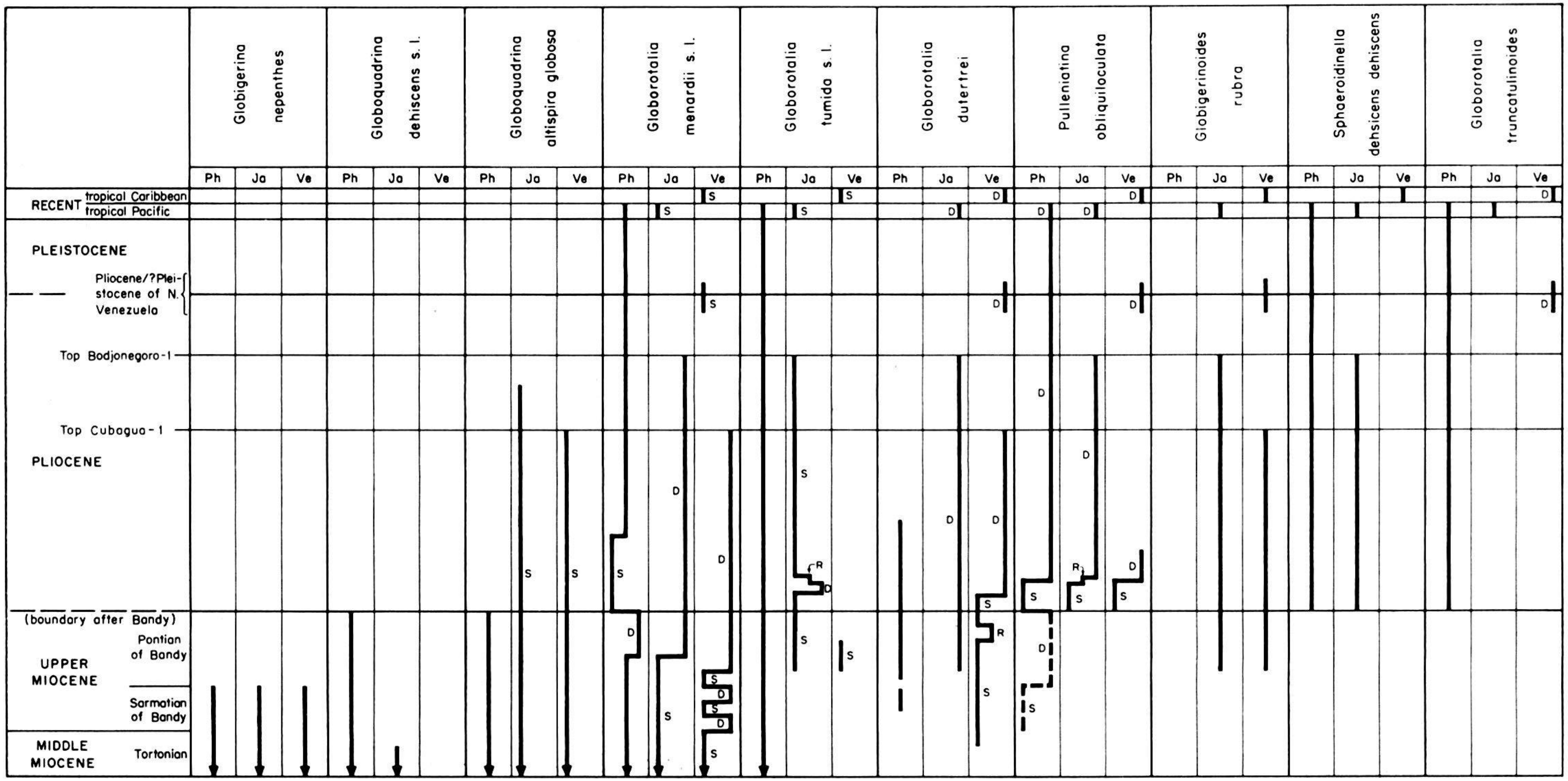

Fig. 1. *Distribution of some planktonic Foraminifera in the Upper Miocene to Recent.* Ranges in the Philippines (Ph) are adopted from BANDY, those from Java (Ja) are based on well Bodjonegoro-1 and those from Venezuela (Ve) on well Cubagua-1, situated on the island of Cubagua, and on surface sections of the Pliocene-? Pleistocene Cumaná beds of Cumaná and the Playa Grande formation of Cabo Blanco, both on the north coast. The distribution of Recent species is based on samples from the tropical Pacific and Caribbean.

S = sinistral coiling, D = dextral coiling, R = random coiling, — — = rare occurrence. Where no letter is shown with a range, the direction of coiling was not investigated.

this short-lived interval of sinistrally coiling *Pulleniatina obliquiloculata* is therefore taken as a tentative datum. It must be pointed out, however, that by accepting this datum one faces disagreement in the ranges of a number of other species, one of them being *Globoquadrina altispira globosa*. In the Philippines, according to BANDY, it disappears at the indicated datum, whereas in Java and on Cubagua the subspecies continues higher (see page 547, *Globoquadrina altispira globosa*). If one were to correlate the lower sinistrally coiling interval of BANDY's Philippine islands Pulleniatinas with the only sinistrally coiling one of Java and Cubagua then *Globoquadrina altispira globosa* would in all three areas continue past this level and the tops would agree better.

The sinistrally coiling short interval of *Pulleniatina obliquiloculata*, as occurs in Cubagua-1 and in neighbouring surface sections on the Peninsula de Araya (north coast of Venezuela, some 30 km from Cubagua), seems ideal for stratigraphic correlation and its position compares rather well with the ranges of some other planktonic foraminiferal species from the far distant Bodjonegoro well of Java. Though, as pointed out, there exists still a number of discrepancies compared with BANDY's results from the Philippines, it seems likely that his short, higher interval of sinistrally coiling Pulleniatinas does in fact correlate with the basal left coiling Pulleniatinas of Java and Cubagua. This characteristic coiling pattern of *Pulleniatina obliquiloculata* during its early range will probably turn out to be a useful feature for long-range stratigraphic correlations.

Sphaeroidinella dehiscens dehiscens (PARKER & JONES)

As already mentioned *Sphaeroidinella dehiscens dehiscens* appears in Java first together with *Pulleniatina obliquiloculata*. On the Philippines it begins with the higher left-coiling interval of *Pulleniatina*. In the Cubagua section the species is not developed.

Globigerina nepenthes TODD

In the Philippines *Globigerina nepenthes* became extinct already before the end of the Miocene (top Sarmatian according to BANDY). A gap thus exists between the top occurrence of *Globigerina nepenthes* and the base of *Pulleniatina obliquiloculata* (common)/*Sphaeroidinella dehiscens dehiscens*. This is confirmed by similar ranges in Bodjonegoro-1 and Cubagua-1 and this long-range agreement suggests that the upper limit of *Globigerina nepenthes* is a valuable correlation horizon.

Seemingly contradicting evidence is recorded from the Nobori formation of Japan (lat. 33°N; long. 134°E), where TAKAYANAGI and SAITO (1962) report *Globigerina nepenthes* and *Pulleniatina obliquiloculata* (predominantly dextral coiling specimens) as occurring together. Furthermore, they regard the Nobori Formation containing these two species as being still of Miocene age. Specimens from the Nobori Formation ascribed by these authors to *Globigerina nepenthes* were kindly made available to the writer by Dr. TAKAYANAGI for comparison with specimens from the Caribbean area and Java. In the writer's opinion, confirmed by Dr. P. J. BERMUDEZ, who also examined them, the Japanese specimens are quite different and cannot be included in *Globigerina nepenthes*. The occurrence of *Pulleniatina obliquiloculata* with *Globorotalia tosaensis* (a species in the writer's opinion closely related to *Globorotalia truncatulinoides*) would indicate for the Nobori Formation a Pliocene rather than a Miocene age. This would also fit the Miocene/Pliocene boundary as proposed by BANDY.

The observed ranges of the following species differ more or less markedly between the sections of Java, the Philippines and Cubagua:

Globoquadrina altispira globosa BOLLI

BANDY (1963a) shows *Globoquadrina altispira globosa* to become extinct at the top of the Miocene, immediately below the more common appearance of sinistrally coiling Pulleniatinas. In Bodjonegoro-1, however, the subspecies continues not only with the sinistrally coiling Pulleniatinas but still goes on for about 450 feet with the dextrally coiling Pulleniatinas before it becomes extinct. In Cubagua-1 *Globoquadrina altispira globosa* exists practically to the top of the section, i.e. approximately 1000 feet above the base of *Pulleniatina obliquiloculata*. The distinctly preferred coiling direction of *Globoquadrina altispira globosa* is sinistral throughout in Bodjonegoro-1 and Cubagua-1.

Globorotalia truncatulinoides (D'ORBIGNY)

BANDY shows *Globorotalia truncatulinoides* as appearing together with *Pulleniatina obliquiloculata* (common) and *Sphaeroidinella dehiscens dehiscens* at the base of the Pliocene. The species is not present in Bodjonegoro-1 and Cubagua-1. In the Pacific, *Globorotalia truncatulinoides* lives today preferably well to the north and south of the equator, in latitudes of around 20–40°. Its absence in Bodjonegoro-1 may thus be explained by a tropical climate that persisted there through the Pliocene as recorded in the well section.

The Bodjonegoro Pliocene planktonic fauna is in fact already closely comparable to that of the Recent tropical Pacific, rich in representatives of the *Globorotalia tumida* complex which today preferably live between latitudes 20°N and S. The presence of abundant *Globigerina bulloides*-like forms (living today preferably in colder waters) in Cubagua-1, particularly in its upper part, would point towards a possibly more suitable environment for early *Globorotalia truncatulinoides*, but none was seen there either. In the general area of Cubagua, *Globorotalia truncatulinoides* appears first only in the surface sections of the Cumaná beds of Cumaná and the Playa Grande formation of the Cabo Blanco Group, both considered to be Pliocene and partly possibly already early Pleistocene. There, the presence of *Globorotalia truncatulinoides* as a rule excludes *Globorotalia menardii* and vice versa, indicating climatical changes within the stratigraphic duration of the formations. TAKAYANAGI and SAITO (1962) show *Pulleniatina obliquiloculata* and *Globorotalia tosaensis* (a form closely related to *Globorotalia truncatulinoides*) to occur together in the Nobori Formation, which they consider to be Miocene but which according to BANDY would already be Pliocene.

Globorotalia tumida (Brady)

Globorotalia tumida is a typical tropical species, restricted today in the Pacific to latitudes between approximately 20°N and S. The species ranges, according to Bandy (1964), from the highest Burdigalian to Recent and it is shown to overlap slightly with *Globorotalia fohsi robusta* in the topmost Burdigalian. The picture in Java, as in Cubagua, is quite a different one. In Bodjonegoro-1, the first specimens that show close relation to the Recent *Globorotalia tumida* appear only shortly before the *Pulleniatina obliquiloculata/Sphaeroidinella dehiscens dehiscens* base, at the same level with some other species, e.g. *Globorotalia dutertrei* (*Globigerina eggeri* of Bandy) and *Globigerinoides rubra.* It is possible that this late appearance at the same level with several other species, may be due to a hiatus or condensation in the Bodjonegoro-1 section. But there remain in Bodjonegoro-1 still over 3000 feet of section between the top of *Globorotalia fohsi robusta* and the first representatives of the *Globorotalia tumida* complex.

The early specimens that can be ascribed to the *Globorotalia tumida* complex in Bodjonegoro-1 and in Cubagua-1 are still sufficiently distinct from the present day forms to allow for a separate subspecies (*Globorotalia tumida praetumida*) which will be proposed in one of the forthcoming papers describing the faunas and their distribution in more detail. From their first occurrence in Bodjonegoro-1 and also in Cubagua-1 the *tumida* forms prefer almost exclusively sinistral coiling. This is in contrast to the *Globorotalia menardii* complex which, at approximately the time of the first appearance of the *Globorotalia tumida* complex, switches from sinistral to dextral coiling, to revert again to sinistral coiling only in the high Pliocene or Pleistocene.

From their first appearance in Bodjonegoro-1 representatives of the *Globorotalia tumida* complex continue to be present until the top of the section. In Cubagua-1 on the other hand the species disappears again after a short but distinct occurrence. This is thought to be due again to adverse local ecological conditions. In contrast to Bodjonegoro-1, *Globorotalia dutertrei* appears in Cubagua-1 earlier than does the *Globorotalia tumida* complex, indicating a probably more complete or unbroken section at this interval and stressing a hiatus or condensation in the Bodjonegoro-1 section. As is the case in Bodjonegoro-1, *Globigerinoides rubra* makes in Cubagua-1 its «second» appearance (see below) with the first occurrence of *Globorotalia tumida* s.l. at which level also takes place the change from sinistral to dextral coiling in the *Globorotalia menardii* complex.

The apparent great discrepancy in the range of the *Globorotalia tumida* complex in the Philippines on the one hand and in Java, Cubagua and elsewhere on the other is porbably due to a different interpretation of the species by Bandy relative to the writer and other authors. It bears note that in widespread records no author, prior to Bandy, had recorded the origin of *Globorotalia tumida* anywhere near as early as in the *Globorotalia fohsi robusta* zone.

Globoquadrina dehiscens dehiscens (Chapman, Parr & Collins)

Bandy (1963a, 1964) shows *Globoquadrina dehiscens dehiscens* to become extinct in the Philippines at the top of the Miocene, i.e. at the *Pulleniatina obliqui-*

loculata/Sphaeroidinella dehiscens dehiscens base. Globoquadrinas of the *dehiscens* complex are rather erratically represented in Bodjonegoro-1 and no specimens were seen higher than in the *Globorotalia menardii* zone, which is still some 900 feet below the *Pulleniatina obliquiloculata/Sphaeroidinella dehiscens dehiscens* base. No *Globoquadrina dehiscens* s.l. at all were noted in the Cubagua-1 section.

Globorotalia menardii (D'ORBIGNY) s.l.

It is generally agreed that the *Globorotalia menardii* complex ranges from the Middle Miocene to Recent. Some of the subspecies or closely related species such as *multicamerata* and *miocenica* have more restricted ranges. The pattern of coiling in the *menardii* complex is of some interest in the three areas Java, Philippines and Cubagua. BANDY (1963b) shows for his Tortonian/Sarmatian interval of the Iloilo section, Panay, Philippines, random coiling for the *Globorotalia menardii* complex, followed by dextral coiling in the Pontian (uppermost Miocene). With the appearance of *Pulleniatina obliquiloculata/Sphaeroidinella dehiscens dehiscens* at the base of the Pliocene there is a sudden switch to sinistral coiling and this direction persists throughout the remaining Lower Pliocene of the section. In his 1964 paper, BANDY no longer differentiates coiling directions in *Globorotalia menardii*.

In contrast, *Globorotalia menardii* s.l. changes in Bodjonegoro-1 from sinistral to dextral coiling already before the onset of *Pulleniatina obliquiloculata* and *Sphaeroidinella dehiscens dehiscens*, at about the same level where *Globorotalia tumida* s.l. appears and *Globigerinoides rubra* makes its «second» appearance (see below). Dextral coiling continues to the top of the Bodjonegoro-1 section. Recent *Globorotalia menardii* s.l. of the tropical Pacific coil sinistrally and a change towards this direction must therefore have taken place higher in the Pliocene or in the Pleistocene.

Cubagua-1 presents a similar picture. There, after predominantly coiling sinistrally with the exception of a few short dextral intervals, *Globorotalia menardii* s.l. switches to dextral coiling before the first *Pulleniatina obliquiloculata* appear and close to the basal occurrence of *Globorotalia tumida* s.l. and the «second» appearance of *Globigerinoides rubra*. Again, *Globorotalia menardii* s.l. does not change its coiling direction any more in the remaining part of the Cubagua-1 section. But in the young Pliocene/?Pleistocene Cumaná beds and the Playa Grande formation of the Cabo Blanco Group, *Globorotalia menardii* s.l. is back again to sinistral coiling, the same direction as found in the specimens living today in the Caribbean Sea.

Globorotalia dutertrei (D'ORBIGNY)

Globorotalia eggeri (Rhumbler) is considered a junior synonym of *Globorotalia dutertrei* (d'Orbigny). BANDY (1963a) gives its range (as *Globigerina eggeri*) in Luzon, Philippines, as from Sarmatian (Upper Miocene) to Lower Pliocene. In Bodjonegoro-1 dextrally coiling *Globorotalia dutertrei* appear shortly before the advent of *Pulleniatina obliquiloculata/Sphaeroidinella dehiscens dehiscens* or shortly below the Miocene/Pliocene boundary as proposed by BANDY. It is, however, felt that a part of the section just below the first occurrence of *Globorotalia dutertrei* could be missing there. Such an assumption is supported by an earlier, sinistrally coiling appearance of *Globorotalia dutertrei* in the Cubagua-1 section. There, a change to dextral coiling takes place only higher in the section, at approximately the level where the *Globorotalia tumida* complex and *Globigerinoides rubra* appear. In both wells *Globorotalia dutertrei* continues dextrally coiling to the top of the sections. It is present in the Upper Pliocene/?Pleistocene Cumaná beds and the Playa Grande formation of the Cabo Blanco Group and still lives today in great numbers, preferably in tropical and subtropical waters and is always coiled dextrally.,

Globigerinoides rubra (d'Orbigny)

Bandy does not include *Globigerinoides rubra* in his charts of selected planktonic foraminiferal species. Its primary and supplementary sutural apertures are always symmetrically placed above the suture of two earlier chambers (see Bolli, 1957, p. 112, fig. 21, No. 6a, 6b). This rather long-ranging characteristic species appears to be of some stratigraphic significance for the following reasons. In the Cipero formation of Trinidad (Bolli, 1957), the species ranges from the *Catapsydrax dissimilis* zone to approximately the top of the *Globorotalia fohsi robusta* zone, where it apparently disappears, only to return again in the young Miocene Melajo formation. In the Pozón section of Falcón, Venezuela, Blow (1959) shows *Globigerinoides rubra* to continue for a short time above the *Globorotalia fohsi robusta* zone into the overlying *Globorotalia mayeri*/*Globorotalia lenguaensis* zone, then to become scarce but to reappear again in numbers towards the top of the Pozón formation.

In Bodjonegoro-1, *Globigerinoides rubra* also continues past the top of the *Globorotalia fohsi robusta* zone but disappears completely well before the extinction of *Globorotalia mayeri*, marker fossil of the overlying zone. After an absence of over 3000 feet the species reappears again in the Bodjonegoro-1 section together with the first specimens of the *Globorotalia tumida* complex and *Globorotalia dutertrei*.

Globigerinoides rubra was not observed in the lower part of the Upper Miocene section of Cubagua-1, but it appears, as in Bodjonegoro-1, together with the first *Globorotalia tumida* s.l., whereas *Globorotalia dutertrei* appears in Cubagua-1 much earlier (see under *Globorotalia dutertrei*).

Today, *Globigerinoides rubra* lives between latitudes approximately 40° N and S in the Pacific, thus showing a fair temperature tolerance. Its apparent temporary disappearance or extreme reduction in number from the top of the *Globorotalia fohsi robusta* zone or slightly higher to high in the Upper Miocene is therefore difficult to explain. In Trinidad, drastic environmental changes are at least in part the reason. But in the sections of Cubagua-1 and in particular of Bodjonegoro-1 no such ecological changes took place that should have been sufficient to have caused the temporary disappearance of *Globigerinoides rubra*.

CONCLUSIONS

These notes on the ranges and coiling patterns of some selected planktonic Foraminifera as observed in Java, the Philippines and Cubagua (summarised in fig. 1) show some good agreement for a number of species. But for others, ranges seem to differ in one area from the other two, or may even be different in all three. With some species agreeing so nicely it is somewhat surprising that others from the same sections should not, some of them being out of line by quite a wide margin.

Possible reasons for such discrepancies have been pointed out above. The human element in differing interpretations of a species can largely be eliminated by investigators either exchanging the types in question or by more carefully consulting original descriptions and figures or, even better, by directly comparing their specimens with holotypes. Once a greater number of sections becomes available for comparison of ranges, hiatuses and condensations masking true ranges in certain sections will be more easily detected than is possible now.

The main obstacle to determining the absolute ranges of tropical Upper Miocene to Recent planktonic Foraminifera is their sensitivity to ecological changes, in particular water temperature. During the Cretaceous, Lower and Middle Tertiary there existed a much broader north-south distribution of identical or very similar planktonic Foraminifera. Certain index species of the Upper Cretaceous, Paleocene and Eocene are found to have extended to at least 50–55° both north and south of the equator. World-wide zonation based on these species was thus relatively easy to establish. However, with the onset of the younger Tertiary until today, warm water planktonic Foraminifera became much more restricted geographically.

With our present knowledge it is still not possible to construct a chart reliably showing all the absolute ranges of tropical young Miocene to Recent planktonic Foraminifera. With additional sections from still other parts of the world it should eventually become feasible to obtain more complete results. But the use of such a chart will, in a geographical sense, always be restricted to a rather narrow belt and it may often remain difficult to determine to what degree the ranges of certain species are controlled by ecological factors.

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Manuscript received July 21, 1964