ARTICULO

ZONATION OF CRETACEOUS TO PLIOCENE MARINE SEDIMENTS BASED ON PLANKTONIC FORAMINIFERA

(ZONACION DE SEDIMENTOS MARINOS DEL CRETACEO HASTA EL PLIOCENO BASADA EN FORAMINIFEROS PLANCTONICOS)

by Hans M. Bolli

Contents of Text

ABSTRACT

The present status of the zonation of Cretaceous to Pliocene warm water marine sediments, based on the distribution of planktonic foraminifera, is reviewed and a sequence of 60 zones proposed for this stratigraphic interval. A first review of Cretaceous to Middle Miocene planktonic foraminiferal zones of Trinidad was given by the writer in 1959. A zonation continuing from the Middle Miocene into the Pliocene was added in 1965 by Bolli & Bermúdez. Other authors published additional intermediate zones which are evidently absent or not yet recognized in Trinidad; they subdivided some of the existing zones further, or proposed different names for them. Some of these additions, further subdivisions and changes are reviewed and discussed in this paper. Where found justified and useful, they are incorporated in the general scheme of planktonic zones, presented on Table 4.

RESUMEN

Se resume el estado actual de la zonación de los sedimentos marinos de aguas cálidas del Cretáceo hasta el Plioceno, basados en la distribución de foraminíferos planctónicos, y se propone una secuencia de 60 zonas en este intervalo estratigráfico. Por primera vez, en 1959, el suscrito presentó un resumen de las zonas foraminiferales planctónicas en Trinidad. En 1965, Bolli & Bermúdez agregaron una zonación que continuaba del Medio Mioceno al Plioceno. Otros autores han publicado ciertas zonas adicionales interpuestas que evidentemente no existen o no han sido reconocidas todavía en Trinidad así como también se han subdividido algunas de las zonas existentes o se les ha aplicado nombres diferentes. En este artículo se resumen y discuten algunas de estas adiciones, subdivisiones y cambios, y donde parecen ser justificables y útiles, se incorporan en el esquema general de zonas planctónicas presentado en la Tabla 4.

INTRODUCTION

Trinidad was one of the first areas where planktonic foraminifera were successfully used for the zonation of Cretaceous and Tertiary marls and calcareous clays. The subdivision of formations into zones based on the stratigraphic ranges of planktonic foraminifera was established specifically for the practical requirements of the oil industry. It had to provide the exploration geologist with a tool that would allow the mapping and subdivision of the thick and monotonous shale and marl series that covers large parts of central and southern Trinidad, where the beds are strongly disturbed as a result of complex tectonic movements and large scale slumping. The subsurface geologist had to apply the established zones for the stratigraphic interpretation and correlation of often overturned and thrusted well sections. An unusually fine zonation was required to subdivide the upper part of the Cipero Formation with its oil bearing Herrera Sands. This was made possible by using the distinct evolutionary changes in Globorotalia fohsi, resulting in the subdivision of this species into four stratigraphically successive subspecies.

With such practical purposes in mind, the zones were defined, whenever possible, by typical and easily identifiable index fossils. In this way not only professional paleontologists, but also locally trained employees, could make routine determinations of the thousands of well and surface samples processed for investigation.

The detailed study of planktonic foraminifera began in Trinidad about 20 years ago, and was largely carried out at the Geological Laboratory of the former Trinidad Leaseholds Ltd. (now Texaco Trinidad Inc.) at Pointe-a-Pierre. Thanks to continuous encouragement by Dr. H. G. Kugler, who early realized the possible value of planktonic foraminifera as index fossils, a concerted effort was made to obtain results quickly. Thanks to the generosity of the management of the company, these results were almost immediately released for publication. A considerable number of papers by Cushman & Renz, Cushman & Stainforth, Stainforth, Brönnimann, Bolli, and Blow appeared between 1945 and 1959. Bolli, 1959a, summarized the results of these papers.

The bio-zones published from Trinidad are essentially the same as originally used for oil company work. These zones have found widespread acceptance and application not only in the neighbouring Caribbean and Gulf Coast regions but also in many other, more distant areas. This appears to be proof that most of the zones originally proposed in Trinidad are also recognizable on a world-wide scale and can be used for intercontinental stratigraphic correlations.

Though many Lower Cretaceous to Middle Miocene formations of Trinidad carry rich faunas of planktonic foraminifera and make this island an appropriate place for their study, it is well known that such investigations are strongly handicapped by the complexity of the island's geology. A sequence of bio-zones based on such disturbed and/or incomplete sections can, therefore, hardly be expected to be comprehensive and it was found necessary to fill gaps from more complete and less disturbed sections outside Trinidad.

Several changes in the Trinidad zonal sequence have already been proposed, others will certainly follow. They include additional zones characterizing stratigraphic intervals evidently absent in Trinidad or not yet recognized, further subdivisions of existing zones, and proposals of different zonal markers or changes in existing names.

A system of bio-zones such as originally established in Trinidad or more completely proposed here is by no means the only way to subdivide Cretaceous and Tertiary sediments based on planktonic foraminifera. Within the rich planktonic faunas one can find other index fossils, or combinations of such that would allow for a variety of similar zonations. Moreover, local conditions may exclude certain zones proposed here, in favour of others based on species not used in this paper. This applies in particular to the young Tertiary, where the tropical/subtropical species, on which these zones are based, are restricted to a progressively narrower tropical to subtropical belt the younger they are. The world-wide application of bio-zones of the younger Tertiary is therefore more and more limited on account of latitude (see Bolli, 1964). The correlations of the zones with the divisions of the standard time scale as given in this paper are tentative, and some may become subject to revisions.

This review and discussion of published zones is divided into three parts, one for the Cretaceous, one for the Paleocene-Eocene and one for the Oligocene-Pliocene. Each part is accompanied by a chart showing the correlation of a number of selected zonal schemes. The 60 zones included on Table 4 are briefly defined, their authors mentioned, and some remarks added where necessary. In addition to the sequence of these 60 zones, the stratigraphic distribution of the corresponding zonal markers is also shown on Table 4.

This compilation, which summarizes the present day status of planktonic foraminiferal zones, has been prepared as a guide for the economic and academic micropaleontologist and to serve as a base for further improvement of this zonal system.

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REVIEW AND DISCUSSION OF PUBLISHED ZONES

This review and discussion of published zones is divided into a Cretaceous, a Paleocene-Eocene and an Oligocene-Pliocene part, each accompanied by a table showing the correlation of selected zonal systems. Some references are made in addition to publications which contain zonal systems but are not discussed in this paper.

Most authors use index fossils to designate their zones. Some prefer a lettering system, others a combination of numbers, letters and index fossils. Using numbers or letters to distinguish a sequence of bio-zones is not recommended for the following reasons:

1. Numbers and letters give no indication as to the stratigraphic position of a zone, but this can usually be deduced from a fossil name.

2. Different authors use different letters or numbers for identical or similar intervals (e.g. Gohrbrandt's Lower Eocene Zone E equals Hillebrandt's Zone F; see Table 2).

3. Different authors use the same letters for different stratigraphic intervals (e.g. Herm subdivides the Upper Cretaceous into zones A-E; Gohrbrandt and Hillebrandt use the same letters for zoning the lower Tertiary, see Tables 1, 2).

4. It is possible that an established zone will be divided again, as done by Hillebrandt, who in 1965 subdivided his Zone A of 1962 into Zone A 1 and Zone A 2 (see Table 2). Supposing Zone A 1 will be subdivided again into say a Zone A 1a and a Zone A 1b and so on, such a system will - contrary to the one using index fossil names - become very unwieldy.

It is to be remembered that the zones designated by letters or figures are in fact based on index fossils and it is therefore difficult to see why authors do not use fossil-names in the first place.

Cretaceous

Species of the genera Globotruncana and Rotalipora belong to the first planktonic foraminifera that were used successfully for biostratigraphic subdivisions and correlations. Authors such as Renz, 1936; Tschachtli, 1941; Gandolfi, 1942; Bolli, 1944, 1951; Cita, 1948 and Sigal, 1952, demonstrated their value as excellent index fossils without, however, making use of them for zonal schemes. It was Marie, 1938, who first proposed a sequence of four Campanian-Maastrichtian zones that were based on Globotruncana species, but partially also on benthonic foraminifera. The first zones based on Globotruncana and Rotalipora species alone were those introduced in North Africa by Dalbiez, 1955, and Sigal, 1955, followed by Bolli's 1957a, 1959, zonation of the Trinidad Upper and Lower Cretaceous. None of these proposed zonal schemes comprises a complete Cretaceous section, but combined - as can be seen on Table 1 - they offer a reasonably continuous zonation from Aptian to Maastrichtian. Klaus, 1959, subdivided the Albian to Santonian of the Préalpes Médianes of Switzerland into Zones 1-7, which is, however, no closer subdivision of this interval than that proposed by Dalbiez.

Herm, 1962, established for the Santonian to Maastrichtian of the Northern Calcareous Alps Zones A-F. His Zone C is defined by the full range of Globotruncana calcarata, a species so far not found in Trinidad, probably due to a hiatus. Dalbiez, 1955, on the other hand, listed this species from Algeria but did not use it as a zonal marker. The short ranged and characteristic Globotruncana calcarata is an excellent index fossil, filling a gap in the Trinidad zonal system and subdividing Dalbiez' Globotruncana elevata Zone. Van Hinte, 1965, and Mohler, 1966, both accepted Globotruncana calcarata as a zonal marker, and it is also included here in the general zonal scheme of Table 4.

Herm subdivided Bolli's Abathomphalus mayaroensis Zone into Zones E and F. He placed the boundary between these two zones at a level where some species of Globotruncana, Rugoglobigerina and Heterohelix become distinctly larger in size, combined with a more pronounced variability within the species. However, the assemblage of species remains essentially the same. Such a distinction of two zones, based merely on size differences with no change in faunal composition, may be of local value but it cannot be accepted for a general zonal scheme as presented on Table 4.

Lehmann, 1966, extended Sigal's zonation into the Cenomanian and Albian. His zonal marker Rotalipora klausi is shown by Lehmann to have the same range as R.ticinensi ticinensis, which was already used in 1957 to name a zone in Trinidad. R. ticinensis ticinensis has priority over R. klausi and is therefore maintained as zonal marker on Table 4.

Also shown on Table 1 are the zonal schemes of van Hinte, 1965, and Mohler, 1966. Van Hinte derived his scheme from literature and that of Mohler is also adopted from various authors.

A subdivision of the higher part of the Lower Cretaceous (Aptian-Albian), based on planktonic foraminifera, was first proposed in 1959 by the present author. As already pointed out at that time, the Trinidad sections, on which the subdivision was based, are stratigraphically incomplete. The zonations of other authors did not reach below the Albian. Further studies on the planktonic foraminifera and their distribution in continuous sections are necessary before a more complete pre-Albian zonation can be established.

The Rotalipora evolutionary sequence, with its rapidly developing and disappearing species and subspecies, provides ideal index fossils for a subdivision of the Cenomanian into several zones. Apparently none of the zonal schemes proposed so far has made really full use of them. It is therefore felt that a careful re-study of the Rotalipora species and subspecies, their interrelation and their stratigraphic ranges, would result in a still better defined subdivision of the Cenomanian. The subdivision of the Cenomanian into four zones as proposed on Table 4 is based primarily on Lehmann, 1966, and on the successive appearance of species used here as zonal markers, as presented by Klaus, 1959.

The zonation of the Turonian to Maastrichtian on Table 4 is largely that of Bolli, 1957, with the following modifications:

1. A Praeglobotruncana gigantea Zone adopted from Sigal, 1955, and Lehmann, 1966, is added for the lower Turonian. No similar fauna was observed in Trinidad at this level, where the younger Rotalipora species such as R. reicheli and R. cushmani are also absent. It must be concluded from this that the Upper Cenomanian and the Lower Turonian are absent in the Trinidad sections studied so far.

2. Globotruncana helvetica replaces G. inornata as zonal marker. Both appear to have the same range. G. helvetica is more easily recognizable, extremely rare in Trinidad but usually common in the Alpine-Mediterranean region.

3. Globotruncana schneegansi replaces G. renzi as zonal marker for the same reasons.

4. The Globotruncana calcarata Zone is added between the G. stuarti and the G. lapparenti tricarinata Zone, filling a gap that apprently exists in Trinidad.

Paleocene-Eocene

Table 2 shows a good agreement between the zones published in 1957 from Trinidad with those subsequently proposed from other parts of the world. Additions or differences in the selected zonal systems as compared with that of Trinidad are:

1. Two zones are inserted below the Paleocene Globorotalia trinidadensis Zone of Trinidad: a Globigerina pseudobulloides/G. daubjergensis Zone was proposed by Leonov & Alimarina, 1961, and a Globigerina eugubina Zone by Luterbacher & Premoli, 1964.

Such zones were not recognized in Trinidad but apparently fill a hiatus which exists there. Their place might also locally be taken there by the reefal Soldado Formation. The G. eugubina Zone with its minute fauna represents the earliest Tertiary. The Globigerina pseudobulloides/G. daubjergensis Zone is intermediate between this basal zone and the Globorotalia trinidadensis Zone. Both are adopted here and included in the general zonal scheme on Table 4.

2. Hillebrandt, 1962, subdivided the Paleocene Globorotalia pusilla pusilla Zone of Trinidad into the Zones C and D. He renamed them in 1965 Globorotalia angulata and Globorotalia pusilla Zone respectively. They can also be recognized in Trinidad, and both are included on the general scheme on Table 4.

3. A probable hiatus was postulated by Bolli, 1957b, to exist between the Globorotalia velascoensis and the G. rex Zone. It is based on a considerable faunal break and abrupt changes in the direction of coiling of some Globorotalia species. Hillebrandt, 1965, subdivided the Globorotalia rex Zone of Bolli, 1957, into a lower Globorotalia subbotinae-marginodentata Zone (G), with the two subzones Globorotalia marginodentata (G_1) and Globorotalia subbotinae (G_2), and an upper, Globorotalia lensiformis Zone (H). It is possible that the older of these zones fills - at least partially - the gap assumed to exist in the Trinidad zonal scheme.

Hillebrandt, 1965, furthermore re-named the Globorotalia formosa formosa Zone of Bolli, 1957b, the Globorotalia formosa-Acarinina angulosa Zone (I) and subdivided it into a lower, Acarinina angulosa Subzone (I_1) and an upper Globorotalia formosa Subzone (I_2).

Moreover, Hillebrandt, 1965, also subdivided Bolli's Globorotalia palmerae Zone into a lower, Globorotalia palmerae-Acarinina aspensis Zone (L) and an upper, Globorotalia caucasica Zone (M). A prominent faunal break is apparent between the Globorotalia palmerae and the Hantkenina aragonensis Zones on Fig. 26, p. 159 of Bolli, 1957c, indicating another likely gap in the Trinidad zonal scheme. The faunal composition of Hillebrandt's Globorotalia caucasica Zone (presence of ancestral forms of Clavigerinella, absence of Globigerina prolata except in the basal part of the zone) provides a link between the Globorotalia palmerae and the Hantkenina aragonensis Zones. An identical or very similar fauna is actually known in Trinidad, and has been designated in oil company reports the "Globigerina 92"

(= Globorotalia pseudomayeri) Zone. Such a zone was earlier thought to be of comparatively little stratigraphic value and was for that reason, and also to avoid unnecessary additions to the zonal scheme, not mentioned in Bolli, 1957c.

4. The potentials for a zonation of Paleocene-Eocene sediments of the Alpine-Mediterranean region based on planktonic foraminiferal faunas were pointed out by Bolli, 1959. Since then, numerous papers have been published confirming this assumption and the results of several are shown on Table 2. In addition to Hillebrandt's work, already mentioned, on the Zumaya-Guetaria section of Spain, they include zonations from Northern and Central Italy and the Northern Calcareous Alps. Though some of these authors preferred letters instead of index fossils to designate their zones, Table 2 clearly shows how well the zones originally proposed in Trinidad can be applied to the Alpine-Mediterranean region. Other papers from this area containing similar results include Herb, 1962, and Eckert, 1963.

5. Eames et al., 1962, introduced a Globigerina turritilina turritilina Zone, characterizing the uppermost Eocene. This zone falls between the level of extinction of Globorotalia cerro-azulensis and Cribrohantkenina danvillensis below and the first appearance of Cassigerinella chipolensis above. Such an interval without the typical Upper Eocene planktonic foraminiferal fauna would preferably be attributed to the Lower Oligocene.

6. Jenkins', 1965, zonation of the New Zealand Paleocene and Eocene is less detailed and uses different index fossils. The reasons for this are apparently particular environmental conditions which prevailed at that time in New Zealand.

7. Reference is finally made to Berggren, 1965a, b on world-wide correlations of Paleocene-Eocene planktonic foraminiferal zones. These publications contain correlations with Russian and American zones that are not included in this paper.

Oligocene-Pliocene

While no major discrepancies exist between the various Cretaceous and Paleocene-Eocene zonal systems, some of the schemes proposed for the Oligocene-Pliocene are less easy to compare.

The Oligocene to Middle Miocene zones as proposed for Trinidad, first by Cushman & Stainforth, 1945, and later in a more detailed way by Bolli, 1957d, were generally accepted and applied to other areas, such as Venezuela (Blow, 1959), Gulf Coast area (Butler, 1962), Israel (Reiss & Gvirtzman, 1964). Bolli & Bermúdez, 1965, published a subdivision by planktonic foraminifera of the upper Middle Miocene to Pliocene, i.e. that part of the younger Tertiary which hitherto was not zoned. The same stratigraphic interval was subdivided quite differently by Banner & Blow, 1965, who partly used other index fossils. Until Banner & Blow furnish full documentation of their zones, amplifying the sketchy outline in their 1965 paper, a correlation of their young Miocene to Pliocene zones with those of Bolli & Bermúdez has to remain tentative.

In the same paper Banner & Blow also proposed a zonal system for the Oligocene to Middle Miocene which is much different from that of Bolli, 1957d (see Table 3). Only two zones remain unchanged, while for others of apparently identical stratigraphic position different zonal markers are proposed. The greatest change is found in the Globorotalia fohsi subspecies zones. In this interval of four zones Banner & Blow introduce three new species as zonal markers. Since no description and no figures are given, they remain nomina nuda for the time being.

Drs. Banner & Blow have, however, kindly supplied the writer with a copy of their manuscript in which they describe and figure these new species, and which they intend to publish in the near future. To explain the correlation of Banner & Blow's new zones with those of Bolli, 1957d, as shown on Table 3, they kindly gave permission to quote the following synonymies from their manuscript: Globorotalia (T.) peripheroronda (with rounded periphery) is the same as G. fohsi barisanensis sensu Bolli, 1950, pl. 15, figs. 5, 6 a-c; 1957d, pl. 28, figs. 8 a-c; Blow, 1959, pl. 17, figs. 110, 111 a-c. Globorotalia (T.) peripheroacuta (with acute periphery) compares with G. fohsi fohsi sensu Bolli, 1950, pl. 15, figs. 4 a-c; 1957d, pl. 28, figs. 10 a-c; Blow, 1959, pl. 17, figs. 112 a-c. Globorotalia (G.) praefohsi (with partially keeled periphery) compares with G. fohsi fohsi sensu Bolli, 1957d, pl. 28, figs. 9 a-b. Globorotalia (G.) fohsi is defined by Blow & Banner as possessing a peripheral carina throughout the last whorl.

Banner & Blow's Zone N-9, Orbulina suturalis-Globorotalia (T.) peripheroronda n. sp., is the same as Bolli's Globorotalia fohsi barisanensis Zone, except that the latter begins at the extinction level of Globigerinatella insueta, whereas Zone N-9 has its base at the first occurrence of Orbulina suturalis.

Banner & Blow's Zones N-10 and N-11 subdivide the Globorotalia fohsi fohsi Zone of Bolli, apparently with the exception of its topmost part, which is - together with Bolli's Globorotalia fohsi lobata and G. fohsi robusta zones - lumped into their N-12, Globorotalia (G.) fohsi, Zone.

Banner & Blow's new treatment of the Globorotalia fohsi group of subspecies, in particular their splitting of such an outstanding evolutionary sequence into two different subgenera and several different species, will be critically reviewed in a separate paper. In the writer's opinion there is no need for most of the proposed changes. The 11 zones between the Globigerina ampliapertura and the Globorotalia fohsi robusta Zone of Bolli, 1957d, are based on well defined and easily recognizable index fossils. With the subdivision of the Globigerinatella insueta Zone into two zones, as shown on Table 4, and as originally proposed by Blow, 1959, the number of zones is the same for that interval as in Banner & Blow, 1965. Their system therefore does not offer a closer subdivision but merely makes use of some different zonal markers and of different interpretations of others, which, in turn result in changed zonal boundaries. Furthermore, Banner & Blow's newly proposed zonal scheme, made up of a combination of zonal markers (often two per zone) and a letter/number system, is, as can be seen on Tables 3 and 4, much more complex than that originally proposed by Bolli, 1957d, 1966, and Bolli & Bermúdez, 1965.

Banner & Blow, in Eames et al., 1962, proposed a Globigerina oligocaenica Zone, occupying a stratigraphic position below Bolli's Globigerina ampliapertura Zone, but separated from it by an interval named by them "not known". The same stratigraphic interval is renamed Cassigerinella chipolensis/Hastigerina micra Zone on Table 4. The reason for this is given under "Description of zones".

Banner & Blow's interval "not known" between their Globigerina oligocaenica Zone and the Globigerina ampliapertura Zone, contains, according to these authors, Globigerina ampliapertura. It is included here in the Globigerina ampliapertura Zone.

Blow, 1959, followed the zonation proposed by Bolli, 1957d, with the following changes and additions. He subdivided the Globigerinatella insueta Zone into a Globigerinatella insueta/Globigerinoides bisphaerica Zone and a Globigerinatella insueta/Globigerina trilobа Zone. Such a subdivision is well documented and is also adopted on Table 4, but to simplify the terminology, the two zones are named here Praeorbulina glomerosa and Globigerinatella insueta Zone respectively. They

are defined and explained under "Descriptions of zones". Blow, 1959, also modified some of the Middle Miocene zones and added two more zones above Bolli's Globorotalia menardii Zone. Reference is made to Bolli & Bermúdez, 1965, where these zones are critically reviewed.

The zonation of Jenkins, 1965, 1966, is, except for its basal part, less detailed than that of Bolli, 1957d. Furthermore, most of Jenkins' zonal markers are different. This is attributed to different planktonic faunal assemblages that prevailed in New Zealand during the younger Tertiary. Many of the tropical to subtropical index fossils evidently did not extend as far south as New Zealand.

The Globigerinoides ruber Zone on Table 4 was originally described by Bolli, 1966, from Java. It lies between the Globorotalia fohsi robusta and the Globorotalia mayeri Zone.

Bolli & Bermúdez, 1965, named four of their Upper Miocene and Pliocene zones with two species names each. Three of these zones can also be adequately defined with a single index fossil as zonal marker. To simplify the zonal scheme of Table 4 the following changes are therefore made:

Zones of Bolli & Bermúdez, 1965	Zones in this Paper
Globorotalia dutertrei/ Globigerinoides obliquus extremus	Globorotalia dutertrei
Globoquadrina altispira altispira/ Globorotalia crassaformis	Globoquadrina altispira altispira
Globorotalia truncatulinoides/ Globorotalia inflata	Globorotalia truncatulinoides

The double name of the Globoquadrina altispira altispira/Globorotalia truncatulinoides Zone is retained because each species is already used for another zone, but combined they characterize the interval of their joint occurrence. The only other zone on Table 4 that bears a double name is the Oligocene Cassigerinella chipolensis/Hastigerina micra Zone, also defined by the overlap of these two species.

Contributions to the zonation and correlation of the Oligocene-Pliocene or part of it, in addition to those discussed above and shown on Table 3, have recently been made by several authors. Reference is here made in particular to Wade, 1964, where the stratigraphic distributions of Tertiary planktonic foraminifera are given in relation to biostratigraphic zonal systems of several authors not included here. Mention is also made of Jenkins, 1965a, who discusses intercontinental correlations based on planktonic foraminifera; to Mc Tavish, 1966, who offers in his study on Tertiary planktonic foraminifera of the British Solomon Islands correlations with Australian and Indo-Pacific faunas; and to Cita, Premoli Silva & Rossi, 1965, who correlate some zonations based on planktonic foraminifera of the Oligocene-Pliocene. Finally, reference is made to Bandy, 1962, 1963 and 1964, whose papers on Cenozoic planktonic foraminiferal zonation were discussed by Stainforth, 1964 and Bolli, 1964.

DESCRIPTION OF ZONES

60 zones, subdividing the Cretaceous and Tertiary, based on planktonic foraminifera, are presented on Table 4, together with the ranges of the corresponding zonal markers. These zones are primarily based on the schemes proposed by the author (1957a, b, c, d; 1959; 1966, and Bolli & Bermúdez, 1965). To fill some evident gaps several zones not recognized in these earlier schemes are adopted from other sources, and a few zones are subdivided further as was suggested by other investigators.

The index fossils, on which the 60 zones are based, lived under warm to moderately warm water conditions. They are therefore only found in tropical to subtropical marine sediments. The Cretaceous and Paleocene-Eocene species used here are found within latitudes of up to at least 50 - 55° N and S. The latitudinal belt containing this type of fauna became progressively narrower during the Oligocene-Pliocene and the species used in this study were therefore restricted more and more to today's tropical and subtropical areas.

Cretaceous

Leupoldina protuberans Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Praeglobotruncana rohri.

Author: Bolli, 1959, p. 258-259.

Biglobigerinella barri Zone

Definition : Interval with zonal marker, from its first occurrence to first occurrence of Praeglobotruncana rohri.

Author : Bolli, 1959, p. 258-259

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora roberti.

Author: Bolli, 1959, p. 258-259.

Remarks: The zone was originally defined by the total range of the zonal marker.

Rotalipora roberti Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora ticinensis ticinensis.

Author: Dalbiez, 1955, p. 166.

Remarks: The zone was originally named Ticinella Zone and defined by the presence of Ticinella (= Rotalipora) roberti until the first occurrence of Thalmanninella (= Rotalipora) ticinensis alpha. The name of the zone was changed to Ticinella roberti Zone by Mohler, 1966, and to Rotalipora roberti Zone in this paper.

Rotalipora ticinensis ticinensis Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora appenninica appenninica.

Author: Dalbiez, 1955, p. 166.

Remarks: The zone was originally named Thalmanninella Zone and renamed Rotalipora ticinensis ticinensis Zone by Bolli, 1957a.

Rotalipora appenninica appenninica Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora brotzeni.

Author: Dalbiez, 1955, p. 166.

Remarks: The zone was originally named Lower Rotalipora Zone and defined by the interval from first occurrence of the zonal marker to first occurrence of Rotalipora appenninica typica. Dalbiez' Lower Rotalipora Zone was renamed Rotalipora appenninica appenninica Zone by Bolli, 1957a.

Rotalipora brotzeni Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora reicheli.

Author: Lehmann, 1966, in press.

Remarks: The zone was originally defined by the range of the zonal marker.

Rotalipora reicheli Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Rotalipora cushmani.

Author: Bolli, in this paper.

Remarks: van Hinte's Rotalipora cushmani-reicheli Zone of 1965 comprises both this zone and the younger Rotalipora cushmani Zone.

Rotalipora cushmani Zone

Definition: Range of zonal marker.

Author: Borsetti, 1962, p. 24.

Remarks: The zone was originally given subzonal rank. See also "Remarks" on Rotalipora reicheli Zone.

Praeglobotruncana gigantea Zone

Definition: Interval with zonal marker, from last occurrence of Rotalipora cushmani to first occurrence of Globotruncana helvetica.

Author: Sigal, J., 1955, p. 158.

Remarks: The zone was originally named Zone à "Grandes Globigerines" seules. Lehmann, 1962, subsequently described Sigal's "Grandes Globigerines" as Praeglobotruncana? gigantea which name is here adopted as zonal marker in preference to Hedbergella gigantea proposed by van Hinte, 1965.

Globotruncana helvetica Zone

Definition: Range of zonal marker.

Author: Dalbiez, 1955, p. 166/167, issued on July 5, 1955; Sigal, 1955, p. 158, séance du 2 mai 1955.

Remarks: The Globotruncana helvetica Zone of Dalbiez and the Zone à Globotruncana helvetica seule by Sigal were published, apparently independently, almost simultaneously.

Globotruncana schneegansi Zone

Definition: Interval with zonal marker, from last occurrence of Globotruncana helvetica to first occurrence of Globotruncana concavata.

Author: Dalbiez, 1955, p. 167.

Remarks: This zone corresponds closely with Sigal's Zone à "grandes Rosalines" seules of 1955.

Globotruncana concavata Zone

Definition: Range of zonal marker.

Author: Sigal, 155, p. 159.

Globotruncana fornicata Zone

Definition: Interval with zonal marker, from last occurrence of Globotruncana concavata to first occurrence of G. stuarti s.l.

Author: Bolli, 1957a, p. 52.

Globotruncana stuarti s.l. Zone

Definition: Interval with the zonal marker, from its first occurrence to first occurrence of G. calcarata.

Author: Bolli, 1957a, p. 52.

Globotruncana calcarata Zone

Definition: Range of zonal marker.

Author: Herm, 1962, p. 23, 29.

Remarks: The zone was originally named Zone C.

Globotruncana lapparenti tricarinata Zone

Definition: Interval with zonal marker, from last occurrence of Globotruncana calcarata to first occurrence of G. gansseri.

Author: Bolli, 1957a, p. 54.

Globotruncana gansseri Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Abathomphalus mayaroensis.

Author: Bolli, 1957a, p. 54.

Abathomphalus mayaroensis Zone

Definition: Range of zonal marker.

Author: Bolli, 1957a, p. 54.

Paleocene-Eocene

Globigerina eugubina Zone

Definition: Range of zonal marker.

Author: Luterbacher & Premoli Silva, 1964, p. 68-70.

Remarks: The zone can readily be determined in thin sections because of the extremely small size of the zonal marker and the other accompanying Globigerina species.

Globorotalia pseudobulloides Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia trinidadensis.

Author: Leonov & Alimarina, 1961, p. 37-38.

Remarks: The zone was originally named Globigerina pseudobulloides/Globigerina daubjergensis Zone. To simplify the terminology of the zonal scheme, only the first of the two zonal markers is retained here.

Globorotalia trinidadensis Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia uncinata.

Author: Bolli, 1957b, p. 62.

Globorotalia uncinata Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia angulata.

Author: Bolli, 1957b, p. 64.

Remarks: This zone included originally also the Globorotalia angulata Zone which is here separated. See "Remarks" on Globorotalia angulata Zone.

Globorotalia angulata Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia pusilla pusilla.

Author: Alimarina, 1963.

Remarks: The zone was originally named Acarinina angulata Zone. Hillebrandt, 1965, renamed his Zone C of 1962 the Globorotalia angulata Zone (C) and correlated it with the lower half of the Globorotalia pusilla pusilla Zone of Bolli, 1957b, and with the Acarinina angulata Zone of Alimarina, 1963. The zone as defined here comprises the upper part of the Globorotalia uncinata Zone of Bolli, 1957b, where Globorotalia angulata is present.

Globorotalia pusilla pusilla Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia pseudomenardii.

Author: Bolli, 1957b, p. 64.

Remarks: See "Remarks" on Globorotalia angulata Zone.

Globorotalia pseudomenardii Zone

Definition: Range of zonal marker.

Author: Bolli, 1957b, p. 64.

Globorotalia velascoensis Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia pseudomenardii to last occurrence of zonal marker.

Author: Bolli, 1957b, p. 64.

Globorotalia rex Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia formosa formosa and G. aragonensis.

Author: Bolli, 1957b, p. 64.

Globorotalia formosa formosa Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globigerina taroubaensis and G. turgida.

Author: Bolli, 1957b, p. 64.

Remarks: The upper boundary of the zone, characterized by the first occurrence of the rather indistinct Globigerina taroubaensis and G. turgida, is rather weakly defined. It may therefore be difficult to distinguish the Globorotalia formosa formosa Zone from the overlying G. aragonensis Zone.

Globorotalia aragonensis Zone

Definition: Interval with zonal marker, from first occurrence of Globigerina taroubaensis and G. turgida to first occurrence of Globorotalia palmerae.

Author: Bolli, 1957b, p. 64.

Remarks: See "Remarks" on Globorotalia formosa formosa Zone.

Globorotalia palmerae Zone

Definition: Range of zonal marker.

Author: Bolli, 1957c, p. 156-158.

Hantkenina aragonensis Zone

Definition: Range of zonal marker.

Author: Bolli, 1957c, p. 158.

Globigerapsis kugleri Zone

Definition: Interval between last occurrence of Hantkenina aragonensis and last occurrence of Globorotalia aragonensis.

Author: Bolli, 1957c, p. 158.

Remarks: The zonal marker appears only in the upper part of the zone, to continue through the two overlying zones.

Globorotalia lehneri Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia aragonensis to first occurrence of Porticulasphaera mexicana.

Author: Bolli, 1957c, p. 158.

Porticulasphaera mexicana Zone

Definition: Range of zonal marker.

Author: Bolli, 1957c, p. 158-159.

Truncorotaloides rohri Zone

Definition: Interval with zonal marker, from last occurrence of Porticulasphaera mexicana to last occurrence of zonal marker.

Author: Bolli, 1957c, p. 159.

Globigerapsis semiinvoluta Zone

Definition: Range of zonal marker.

Author: Bolli, 1957c, p. 159-160.

Globorotalia cerro-azulensis Zone

Definition: Interval with zonal marker, from last occurrence of Globigerapsis semiinvoluta to last occurrence of zonal marker.

Author: Bolli, 1957c, p. 160.

Remarks: The zone was originally named Globorotalia cocoaensis Zone. This species turned out to be a junior synonym of Globorotalia cerro-azulensis and the zonal designation was changed accordingly by Bolli, 1959a.

Oligocene-Pliocene

Cassigerinella chipolensis/Hastigerina micra Zone

Definition: Joint occurrence of zonal markers.

Author: Banner & Blow in Eames et al., 1962, p. 68-69.

Remarks: The zone was originally named Globigerina oligocaenica Zone and defined by the range of the zonal marker and also by the overlap of Hastigerina micra with Cassigerinella chipolensis which, according to Banner & Blow, coincides with the range of Globigerina oligocaenica.
Globigerina oligocaenica was subsequently found to be a junior synonym of Globigerina sellii and the name of the zone had to be changed accordingly (e.g. in Reiss & Gvirtzman, 1964).
The present author prefers to identify this stratigraphic interval with the overlap of the two small but characteristic and easily identifiable species Cassigerinella chipolensis and Hastigerina

micra, instead of the range of Globigerina sellii. This latter species, when not well preserved, may be difficult to distinguish from similar Globigerinas, such as G. rohri.

Globigerina ampliapertura Zone

Definition: Interval between last occurrence of Hastigerina micra and first occurrence of Globorotalia opima opima.

Author: Bolli, 1957d, p. 100.

Remarks: The zonal marker is not present in the uppermost part of the zone as defined above. The interval between the last occurrence of Globigerina ampliapertura and the first occurrence of Globorotalia opima opima is characterized in Trinidad by a fauna in which a species close to Globigerina venezuelana is often dominant. This interval was treated in oil company reports as a separate "Globigerina cf. venezuelana Zone". Such a zone was however not included in the zonal scheme of Bolli, 1957d, for the same reasons as the "Globorotalia pseudomayeri Zone" was also left out in the Eocene (see Paleocene-Eocene part of the "Review and discussion of published zones").

Globorotalia opima opima Zone

Definition: Range of zonal marker.

Author: Bolli, 1957d, p. 100.

Globigerina ciperoensis ciperoensis Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia opima opima to first occurrence of Globorotalia kugleri.

Author: Cushman & Stainforth, 1945, p. 4.

Remarks: The zone was originally named Globigerina concinna Zone, limited below by the Hospital Hill Marl (Upper Eocene part of the Navet Formation) and above by the Globigerinatella insueta Zone of Cushman & Stainforth. Thus the zone included in its original sense a much wider stratigraphic interval than that defined later by Bolli, 1957d, p. 100 and used here.

Globorotalia kugleri Zone

Definition: Range of zonal marker.

Author: Bolli, 1957d, p. 100-101.

Catapsydrax dissimilis Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia kugleri to first occurrence of Globigerinatella insueta.

Author: Cushman & Renz, 1947, p. 3.

Remarks: The above definition is that of Bolli, 1957d.
The zone was originally described as the Globigerina dissimilis Zone, falling between the Globigerina concinna and Globigerinatella insueta zones of Cushman and Stainforth. It thus included the Globorotalia kugleri and Catapsydrax dissimilis zones, and probably also the Catapsydrax stainforthi Zone, as they are defined in this paper.

Catapsydrax stainforthi Zone

Definition: Interval with zonal marker, from first occurrence of Globigerinatella insueta to last occurrence of Catapsydrax dissimilis.

Author: Bolli, 1957d, p. 101.

Globigerinatella insueta Zone

Definition: Interval with zonal marker, from last occurrence of Catapsydrax dissimilis to first occurrence of Praeorbulina glomerosa.

Author: Cushman & Stainforth, 1945, p. 4-5.

Remarks: The zone included originally a thicker, not precisely defined interval. Comparing it with their younger Globorotalia fohsi Zone, Cushman & Stainforth stated that "these two zones contain very similar rich faunas, almost the only difference being an abundance of Globorotalia fohsi and G. canariensis in the upper zone". Bolli, 1957d, defined the zone as limited below by the last occurrence of Catapsydrax dissimilis and above by the last occurrence of the zonal marker. He referred in that paper to Blow's, 1956, study of the origin and evolution of the genus Orbulina within the Globigerinatella insueta Zone and stated: "Based on these evolutionary trends, a further subdivision of the upper part of the Globigerinatella insueta Zone could readily be established". A subdivision was then formally proposed by Blow, 1959, who subdivided the zone into a lower, Globigerinatella insueta/Globigerinoides triloba Subzone and an upper, Globigerinatella insueta/Globigerinoides bispherica Subzone. & Blow, 1965, changed these subzones to N-7, Globigerinatella insueta-Globigerinoides quadrilobus trilobus Zone and N-8, Globigerinoides sicanus-Globigerinatella insueta Zone respectively. To simplify the terminology of the zonal scheme, the lower of these two zones is here simply called Globigerinatella insueta Zone and the upper Praeorbulina glomerosa Zone, and both defined accordingly. Their joint boundary lies slightly higher than that of Blow, 1959, and Banner & Blow, 1965.

Praeorbulina glomerosa Zone

Definition: Interval with zonal marker, from its first occurrence to last occurrence of Globigerinatella insueta.

Author: Blow, 1959, p. 77.

Remarks: The zone was originally named Globigerinatella insueta/Globigerinoides bispherica Subzone and its lower boundary taken slightly deeper stratigraphically than in the above definition. Jenkins, 1966, introduced a Praeorbulina glomerosa curva Zone for an interval between the first occurrence of Praeorbulina glomerosa curva and the first occurrence of Orbulina suturalis. See also "Remarks" on Globigerinatella insueta Zone.

Globorotalia fohsi Zone

Cushman & Stainforth, 1945, introduced a Globorotalia fohsi Zone. The boundary between this zone and their underlying Globigerinatella insueta Zone was not well defined, as already pointed out in the "Remarks" on the Globigerinatella insueta Zone. The upper boundary of Cushman & Stainforth's Globorotalia fohsi Zone is on the other hand clearly marked by the extinction of many foraminiferal species, including the zonal marker.

Bolli, 1950, subdivided Globorotalia fohsi into the four stratigraphically successive subspecies Globorotalia fohsi barisanensis, G. fohsi fohsi, G. fohsi lobata and G. fohsi robusta and used them later (1951a) as subzonal and (1957d) as zonal markers.

Globorotalia fohsi barisanensis Zone

Definition: Interval with zonal marker, from last occurrence of Globigerinatella insueta to first occurrence of Globorotalia fohsi fohsi.

Author: Bolli, 1957d, p. 101.

Globorotalia fohsi fohsi Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia fohsi lobata.

Author: Bolli, 1957d, p. 101.

Globorotalia fohsi lobata Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia fohsi robusta.

Author: Bolli, 1957d, p. 101.

Globorotalia fohsi robusta Zone

Definition: Range of zonal marker.

Author: Bolli, 1957d, p. 101-102.

Globigerinoides ruber Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia fohsi robusta to last Middle Miocene occurrence of zonal marker.

Author: Bolli, 1966, in press.

Remarks: The zone represents a stratigraphic interval that was previously not, or only very indistinctly, recognized in the Caribbean region. There, Globigerinoides ruber disappeared simultaneously with Globorotalia fohsi robusta, or very shortly afterwards. In Java the distribution of the Bodjonegoro-1 planktonic foraminifera (Bolli, 1966) shows that Globigerinoides ruber may persist for a considerable time after the extinction of Globorotalia fohsi robusta (in Bodjonegoro-1 for over 200 meters). The Globigerinoides ruber Zone was introduced to divide an otherwise overly thick Globorotalia mayeri Zone in the Java section. Its recognition also stresses a hiatus that exists elsewhere, between the Globorotalia fohsi robusta and the Globorotalia mayeri Zone, for instance in Trinidad. Such a hiatus was previously indicated there by an abrupt lithological change and also by the presence of pebble beds. It is known, that the widespread disappearance of Globigerinoides ruber in the Middle Miocene is only a temporary one, probably caused by the onset of conditions not tolerated by the species. It is assumed that the species continued to live locally isolated or in an endemic way until its widespread re-appearance in the Upper Miocene Globorotalia margaritae Zone.

Globorotalia mayeri Zone

Definition: Interval with zonal marker, from last Middle Miocene occurrence of Globigerinoides ruber to last occurrence of zonal marker.

Author: Brönnimann, 1951a, p. 131.

Remarks: The zone as originally defined also included the Globigerinoides ruber Zone (see "Remarks" on the latter). Brönnimann (1951) mentioned the Globorotalia mayeri Zone, but only in his later paper (1951a) gave the basis for its separation from the overlying G. menardii Zone and the underlying G. fohsi Zone.

Globorotalia menardii Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia mayeri to first occurrence of Globorotalia acostaensis.

Author: Stainforth, 1948, p. 1303.

Remarks: The zone as defined originally included the whole Lengua Formation of Trinidad. Brönnimann, 1951a, subdivided Stainforth's zone into a lower, Globorotalia mayeri Zone and an upper, Globorotalia menardii Zone, with the boundary between the two zones marked by the extinction of G. mayeri.

Environmental changes caused a rapid disappearance of planktonic foraminifera at the top of the Lengua Formation, hence the top of the Globorotalia menardii Zone could not be established there. The above definition of the zone is based on more favorable sections recently investigated in coastal Eastern Venezuela by Bolli & Bermúdez, 1965, and in Java by Bolli, 1966.

Globorotalia acostaensis Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia dutertrei.

Author: Bolli & Bermúdez, 1965, p. 130-131.

Globorotalia dutertrei Zone

Definition: Interval with zonal marker, from its first occurrence to first occurrence of Globorotalia margaritae.

Author: Bolli & Bermúdez, 1965, p. 131.

Remarks: The zone was originally named Globorotalia dutertrei/Globigerinoides obliquus extremus Zone. To simplify the terminology of the zonal scheme, only the first of the two zonal markers is retained here.

Globorotalia margaritae Zone

Definition: Range of zonal marker.

Author: Bolli & Bermúdez, 1965, p. 132.

Globoquadrina altispira altispira Zone

Definition: Interval with zonal marker, from last occurrence of Globorotalia margaritae to first occurrence of Globorotalia truncatulinoides.

Author: Bolli & Bermúdez, 1965, p. 133.

Remarks: The zone was originally named Globoquadrina altispira altispira/ Globorotalia crassaformis Zone. To simplify the terminology of the zonal scheme, only the first of the two zonal markers is retained here.

Globoquadrina altispira altispira/Globorotalia truncatulinoides Zone

Definition: Joint occurrence of zonal markers.

Author: Bolli & Bermúdez, 1965, p. 133-134.

Globorotalia truncatulinoides Zone

Definition: Interval with zonal marker above last occurrence of Globoquadrina altispira altispira.

Author: Bolli & Bermúdez, 1965, p. 134-135.

Remarks: The zone was originally named Globorotalia truncatulinoides/ Globorotalia inflata Zone. To simplify the terminology of the zonal scheme, only the first of the two zonal markers is retained here. The limited value of the zone, which may extend to Recent, is discussed in Bolli & Bermúdez, 1965.

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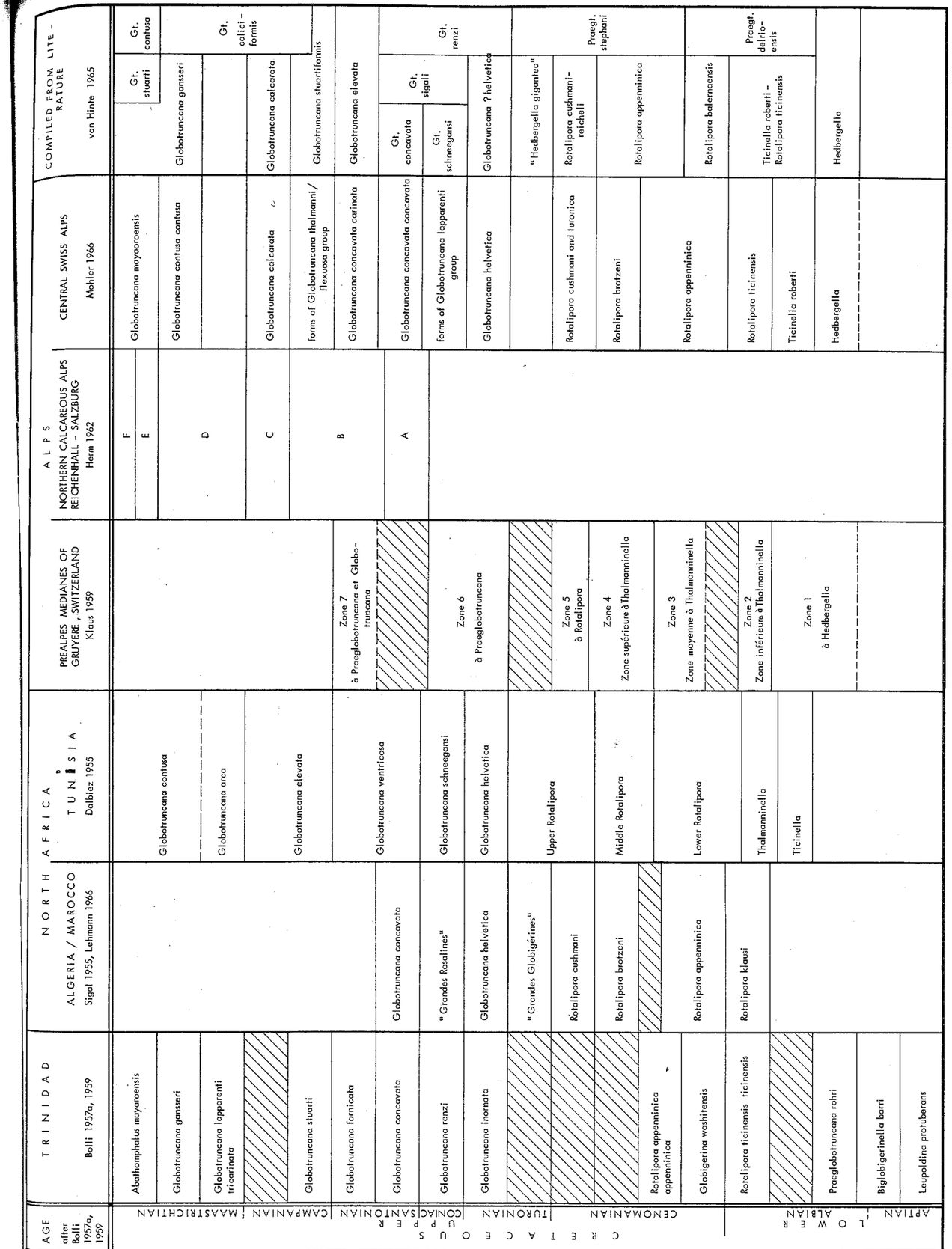

TABLE 1: CORRELATION OF SOME CRETACEOUS ZONAL SUBDIVISIONS BASED ON PLANKTONIC FORAMINIFERA

AGE after Bolli 1957d & Bolli & Bermudez 1965	TRINIDAD - NE VENEZUELA - JAMAICA - JAVA Bolli 1957d, Bolli & Bermudez 1965, Bolli 1966	NW - VENEZUELA (FALCON) Blow 1959	CARIBBEAN, AFRICA, etc. Banner & Blow in Eames et al. 1962	ISRAEL Reiss & Gvirtzman 1964	CARIBBEAN - PACIFIC - ALPINE / MEDITERRANEAN ETC. Banner & Blow 1965	NEW ZEALAND Jenkins 1965, 1966
PLIOCENE	Globorotalia truncatulinoides / Globorotalia inflata				N 22. Globorotalia (G.) truncatulinoides	Globorotalia (T.) inflata (lower part of zone only)
	Globoquadrina altispira altispira / Globorotalia truncatulinoides				N 21. Globorotalia (G.) tosaensis	
MIOCENE UPPER	Globoquadrina altispira altispira / Globorotalia crassaformis				N 20. Globorotalia (G.) multicamerata - Pulleniatina obliquiloculata (s.s.)	Globorotalia (G.) miozea sphericomiozea
	Globorotalia margaritae				N 19. Sphaeroidinella dehiscens (s.s.) - Globoquadrina altispira (s.s.)	
	✓ Globorotalia dutertrei / Globigerinoides obliquus extremus				N 18. Globorotalia (G.) tumida tumida - Sphaeroidinellopsis subdehiscens	
					N 17. Globorotalia (G.) tumida plesiotumida	
MIOCENE MIDDLE	✓ Globorotalia acostaensis	Globigerina bulloides		Globigerina bulloides	N 16. Globorotalia (T.) acostaensis (s.s.) - Globorotalia (G.) merotumida	Globorotalia (G.) miotumida miotumida
		Sphaeroidinella seminulina		Sphaeroidinella seminulina		
	Globorotalia menardii	Globorotalia menardii menardii / Globigerina nepenthes		Globorotalia cultrata / Globigerina nepenthes	N 15. Globorotalia (T.) continuosa	
	Globorotalia mayeri	Globorotalia mayeri / Globigerina nepenthes		Globorotalia mayeri	N 14. Globigerina nepenthes - Globorotalia (T.) siakensis	Globorotalia (T.) mayeri mayeri
		Globorotalia mayeri / Globorotalia lenguaensis			N 13. Sphaeroidinellopsis subdehiscens - Globigerina n.sp. aff. nepenthes	
	Globigerinoides ruber					
MIOCENE LOWER	Globorotalia fohsi robusta	Globorotalia fohsi robusta		Globorotalia fohsi robusta	N 12. Globorotalia (G.) fohsi	
	Globorotalia fohsi lobata	Globorotalia fohsi lobata		Globorotalia fohsi lobata		
	Globorotalia fohsi fohsi	Globorotalia fohsi fohsi		Globorotalia fohsi fohsi	N 11. Globorotalia (G.) praefohsi	Orbulina suturalis
	✓ Globorotalia fohsi barisanensis	Globorotalia fohsi barisanensis		Globorotalia fohsi barisanensis	N 10. Globorotalia (T.) peripheroacuta	
	Globigerinatella insueta	Globigerinatella insueta / Globigerinoides bisphaerica		Globigerinatella insueta	N 9. Orbulina suturalis - Globorotalia (T.) peripheroronda n.sp.	Praeorbulina glomerosa curva
		Globigerinatella insueta / Globigerinoides trilobata			N 8. Globigerinoides sicanus - Globigerinatella insueta	
	Catapsydrax stainforthi	Catapsydrax stainforthi		Globigerinita stainforthi	N 7. Globigerinatella insueta - Globigerinoides quadrilobus trilobus	Globigerinoides trilobus trilobus
	Catapsydrax dissimilis	Catapsydrax dissimilis		Globigerinita dissimilis	N 6. Globigerinatella insueta - Globigerinita dissimilis (s.l.)	
OLIGOCENE	Globorotalia kugleri			Globorotalia kugleri	N 5. Globoquadrina dehiscens praedehiscens - G. dehiscens dehiscens	
	Globigerina ciperoensis ciperoensis		Globigerina ouachitaensis ciperoensis	Globigerina ouachitaensis ciperoensis	N 4. Globorotalia (T.) kugleri	Globigerina (G.) woodi connecta
	Globorotalia opima opima		Globorotalia opima opima	Globorotalia opima opima	N 3. Globigerina angulisuturalis	Globigerina (G.) woodi woodi
						Globoquadrina dehiscens
					N 2. Globigerina angulisuturalis - Globorotalia (T.) opima (s.s.)	Globigerina (G.) euapertura
	Globigerina ampliapertura		Globigerina ampliapertura	Globorotalia ampliapertura	N 1. Globigerina ampliapertura	Globigerina (S.) angiporoides angiporoides
			not known	unnamed		
			Globigerina oligocaenica	Globigerina sellii		

TABLE 3 : CORRELATION OF SOME OLIGOCENE TO PLIOCENE ZONAL SUBDIVISIONS BASED ON PLANKTONIC FORAMINIFERA

TABLE 4

ZONATION OF CRETACEOUS TO PLIOCENE MARINE SEDIMENTS BASED ON PLANKTONIC FORAMINIFERA

RANGES OF ZONAL MARKERS

after Bolli 1957a, b, c, d; 1959; 1966;
Bolli & Bermudez 1965; with some modifications and additions

AGE		ZONES
TERTIARY	NEOGENE PLIOCENE	GLOBOROTALIA TRUNCATULINOIDES
		GLOBOQUADRINA ALTISPIRA ALTISPIRA/ GLOBOROTALIA TRUNCATULINOIDES
	NEOGENE MIOCENE UPPER	GLOBOQUADRINA ALTISPIRA ALTISPIRA
		GLOBOROTALIA MARGARITAE
		GLOBOROTALIA DUTERTREI
	NEOGENE MIOCENE MIDDLE	GLOBOROTALIA ACOSTAENSIS
		GLOBOROTALIA MENARDII
		GLOBOROTALIA MAYERI
		GLOBIGERINOIDES RUBER
	NEOGENE MIOCENE LOWER	GLOBOROTALIA FOHSI ROBUSTA
		GLOBOROTALIA FOHSI LOBATA
		GLOBOROTALIA FOHSI FOHSI
		GLOBOROTALIA FOHSI BARISANENSIS
		PRAEORBULINA GLOMEROSA
		GLOBIGERINATELLA INSUETA
		CATAPSYDRAX STAINFORTHI
		CATAPSYDRAX DISSIMILIS
	PALEOGENE OLIGOCENE	GLOBOROTALIA KUGLERI
		GLOBIGERINA CIPEROENSIS CIPEROENSIS
		GLOBOROTALIA OPIMA OPIMA
		GLOBIGERINA AMPLIAPERTURA
		CASSIGERINELLA CHIPOLENSIS / HASTIGERINA MICRA
	PALEOGENE EOCENE UPPER	GLOBOROTALIA CERRO-AZULENSIS
		GLOBIGERAPSIS SEMIINVOLUTA
		~~TRUNCOROTALOIDES~~ TRUNCATULINOIDES ROHRI
	PALEOGENE EOCENE MIDDLE	PORTICULASPHAERA MEXICANA
		GLOBOROTALIA LEHNERI
		GLOBIGERAPSIS KUGLERI
		HANTKENINA ARAGONENSIS
	PALEOGENE EOCENE LOWER	GLOBOROTALIA PALMERAE
		GLOBOROTALIA ARAGONENSIS
		GLOBOROTALIA FORMOSA FORMOSA
		GLOBOROTALIA REX
	PALEOCENE	GLOBOROTALIA VELASCOENSIS
		GLOBOROTALIA PSEUDOMENARDII
		GLOBOROTALIA PUSILLA PUSILLA
		GLOBOROTALIA ANGULATA
		GLOBOROTALIA UNCINATA
		GLOBOROTALIA TRINIDADENSIS
		GLOBOROTALIA PSEUDOBULLOIDES
		GLOBIGERINA EUGUBINA
CRETACEOUS	UPPER MAASTRICHTIAN	ABATHOMPHALUS MAYAROENSIS
		GLOBOTRUNCANA GANSSERI
		GLOBOTRUNCANA LAPPARENTI TRICARINATA
	UPPER CAMPANIAN	GLOBOTRUNCANA CALCARATA
		GLOBOTRUNCANA STUARTI s. l.
	UPPER SANTONIAN	GLOBOTRUNCANA FORNICATA
		GLOBOTRUNCANA CONCAVATA
	UPPER CONIACIAN	GLOBOTRUNCANA SCHNEEGANSI
	UPPER TURONIAN	GLOBOTRUNCANA HELVETICA
		PRAEGLOBOTRUNCANA GIGANTEA
	UPPER CENOMANIAN	ROTALIPORA CUSHMANI
		ROTALIPORA REICHELI
		ROTALIPORA BROTZENI
		ROTALIPORA APPENNINICA APPENNINICA
	LOWER ALBIAN	ROTALIPORA TICINENSIS TICINENSIS
		ROTALIPORA ROBERTI
		PRAEGLOBOTRUNCANA ROHRI
	LOWER APTIAN	BIGLOBIGERINELLA BARRI
		LEUPOLDINA PROTUBERANS

LEUPOLDINA PROTUBERANS
BIGLOBIGERINELLA BARRI
PRAEGLOBOTRUNCANA ROHRI
ROTALIPORA ROBERTI
ROTALIPORA TICINENSIS TICIN.
ROTALIPORA APPENNINICA APP.
ROTALIPORA BROTZENI
ROTALIPORA REICHELI
ROTALIPORA CUSHMANI
PRAEGLOBOTRUNCANA GIGANTEA
GLOBOTRUNCANA HELVETICA
GLOBOTRUNCANA SCHNEEGANSI SCHNEEGANSI
GLOBOTRUNCANA CONCAVATA
GLOBOTRUNCANA FORNICATA
GLOBOTRUNCANA STUARTI s. l.
GLOBOTRUNCANA CALCARATA
GLOBOTRUNCANA LAPP. TRIC.
GLOBOTRUNCANA GANSSERI
ABATHOMPHALUS MAYAROENSIS
GLOBIGERINA EUGUBINA
GLOBOROTALIA PSEUDOBULL.
GLOBOROTALIA TRINIDADENSIS
GLOBOROTALIA UNCINATA
GLOBOROTALIA ANGULATA
GLOBOROTALIA PUSILLA PUSILLA
GLOBOROTALIA PSEUDOMENARDII
GLOBOROTALIA VELASCOENSIS
GLOBOROTALIA REX
GLOBOROTALIA FORMOSA FORM.
GLOBOROTALIA ARAGONENSIS
GLOBOROTALIA PALMERAE
HANTKENINA ARAGONENSIS
GLOBIGERAPSIS KUGLERI
GLOBOROTALIA LEHNERI
PORTICULASPHAERA MEXICANA
~~TRUNCOROTALOIDES~~ TRUNCATULINOIDES ROHRI
GLOBIGERAPSIS SEMIINVOLUTA
GLOBOROTALIA CERRO-AZULEN.
CASSIGERINELLA CHIPOLENSIS
HASTIGERINA MICRA
GLOBIGERINA AMPLIAPERTURA
GLOBOROTALIA OPIMA OPIMA
GLOBIGERINA CIPEROENSIS CIP.
GLOBOROTALIA KUGLERI
CATAPSYDRAX DISSIMILIS
CATAPSYDRAX STAINFORTHI
GLOBIGERINATELLA INSUETA
PRAEORBULINA GLOMEROSA
GLOBOROTALIA FOHSI BARIS.
GLOBOROTALIA FOHSI FOHSI
GLOBOROTALIA FOHSI LOBATA
GLOBOROTALIA FOHSI ROBUSTA
GLOBIGERINOIDES RUBER
GLOBOROTALIA MAYERI
GLOBOROTALIA MENARDII
GLOBOROTALIA ACOSTAENSIS
GLOBOROTALIA DUTERTREI
GLOBOROTALIA MARGARITAE
GLOBOQUADRINA ALTISPIRA ALT.
GLOBOROTALIA TRUNCATULINOID ES