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PLANKTONIC FORAMINIFERA

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Contenido — Página

Selección de artículos, resposabilidad de : Raúl Gío-Argaez.

Superfamilia Globigerinaceae : preparado por Ma. Luisa Robles Ramos en colaboración con : Clara Flores Covarrubias y Miguel Gómez Ponce I.M.P. México Marzo 1967.

INTRODUCCION

La composición de la pared y la microestructura de la testa, es de gran importancia para la clasificación del Orden Foraminiferida, ya que las características de la testa está determinada por la naturaleza del protoplasma secretado. La composición química básica y el arreglo radial o granular de los cristales de calcita se utilizan para reconocer los caracteres de mayor significado en cuanto a Superfamilias.

Comúnmente la testa de los foraminíferos presenta una o más aberturas, pudiendo tener además finas perforaciones a través de las cuales salen los pseudópodos granulo-reticulosos.

En términos generales sirve de base para la clasificación: el material de que está constituída la testa, la disposición de las cámaras, la forma y posición de la abertura y las modificaciones aberturales que son caracteres constantes. La ornamentación, forma y número de las cámaras, tipo de suturas, son características más bien específicas. En algunos casos el tamaño de la testa es también significativo.

La reproducción puede ser sexual o asexual en forma alternante o irregular, originando formas microsféricas (asexual) y megalosféricas (sexual). Estas formas se encuentran generalmente juntas y han sido nombradas: megalosféricas a las de pequeño tamaño con proloculum o cámara inicial grande y microsféricas a las de tamaño mayor con proloculum pequeño.

El fondo del mar en conjunto constituye el llamado sistema bentónico en tanto que el de las aguas se denomina pelágico.

La mayor parte de las especies de los foraminíferos son bentónicos viviendo en o cerca del fondo, se desplazan con gran lentitud por medio de sus pseudópodos y en su mayoría están controlados por factores físicos: profundidad, temperatura, cantidad de luz, turbidez, turbulencia de las aguas y características del fondo de los sedimentos; los factores químicos son: salinidad del agua y sus elementos disponibles; los factores biológicos los suministra el alimento de que disponen: organismos simbióticos, parásitos y predatores.

Debido a que los foraminíferos bentónicos están controlados por las condiciones antes expresadas y al poco desplazamiento que tienen, el conocimiento de ellos, permite la reconstrucción de medios de depósito.

Durante el Jurásico Superior se inicia la adaptación de los foraminíferos a la vida en el plancton, y en el Cretácico se observa el apogeo de estas formas, hecho de gran significación, porque este tipo de habitat permitió una extensa distribución geográfica de esos microorganismos que se encuentran en grandes cantidades, haciéndolos importantes para efectuar correlaciones bioestratigráficas a grandes distancias.

III.- FORAMINIFEROS PLANCTONICOS

SUPERFAMILIA GLOBIGERINACEA, CARPENTER, PARKER Y JONES, 1862

Los foraminíferos planctónicos pertenecen a la superfamilia GLOBIGERINACEA; su posición taxonómica es la siguiente.

Phylum	Protista Goldfuss, 1821
Subphylum	Sarcodina Schamarda, 1871
Clase	Reticularea Lankester, 1885
Subclase	Granuloreticulosia Saedleer, 1934
Orden	Foraminiferida Eichwald, 1830
Suborden	Rotaliina Delage y Hérouard, 1896

Superfamilia GLOBIGERINACEA, Carpenter, Parker y Jones, 1862

Los globigerináceos son organismos planctónicos que viven libremente en aguas marinas.

Desde el punto de vista ecológico, organismos pelágicos son aquellos que habitan en el océano y que se sostienen flotando. Una intensa vida se desarrolla en este habitat, donde se encuentran no solamente los protozoarios y plantas microscópicas sino también tenóforos, cefalópodos, copépodos y peces

La vida pelágica en el aspecto ecológico se subdivide en el necton, en el que se incluyen los que nadan libremente, es decir que para desplazarse no dependen de los movimientos marinos, y el plancton, que comprende organismos flotantes, y cuyo movimiento es insignificante en comparación con el de las aguas donde viven.

Importancia Estratigráfica.- Durante las últimas dos décadas, el interes despertado por el estudio de los foraminíferos planctónicos ha sido extraordinario pues se ha reconocido como indudable su valor como fósiles índices, ya que ofrecen excelentes bases para correlacionar áreas regionales e intercontinentales, por presentar una dispersión horizontal muy grande y un alcance vertical restringido, por otra parte, únicamente son atacados por factores del medio salino, por variaciones de la temperatura y turbidez. Al morir, sus testas se depositan en el piso marino, formando verdaderos fangos, (lodos de Globigerina) los cuales cubren en la actualidad enormes superficies.

Importancia Paleoecológica.- La importancia de los foraminíferos planctónicos para determinar este aspecto es más bien relativa, pues las formas bentónicas son las más indicadas para determinar los medios marinos, a las formas planctónicas se les considera importantes para indicar las condiciones climáticas de las aguas marinas, y su distribución en el Reciente, según se ilustra en el siguiente cuadro:

DISTRIBUCION DE FORAMINIFEROS PLANCTONICOS EN DISTINTAS LATITUDES DEL OCEANO PACIFICO. *

	← FRIA →		← CALIDA →	
ESPECIES	FAUNA SUB-ARTICA	FAUNA DE TRANSICION	FAUNA CENTRAL	FAUNA ECUATORIAL OESTE-CENT.
Globigerina pachiderma	———			
Globigerinoides cf. minuta	———			
Globigerina quinqueloba	———	- - - - -	- - - - -	- - - - -
Globigerina bulloides	———	———	- - - - -	- - - - -
Globigerina eggeri(pequeña)	———	———	- - - - -	- - - - -
Globigerinita glutinata	- - - - -	- - - - -	———	———
Globigerina eggeri (grande)		———	- - - - -	- - - - -
Orbulina universa		———	———	———
Globorotalia scitula		- - - - -	- - - - -	- - - - -
Globigerinoides rubra		———	———	———
Globigerinella aequilateralis		———	———	———
Globigerina sp.		- - - - -	- - - - -	- - - - -
Globigerina hexagona			- - - - -	- - - - -
Hastigerina pelagica		———	———	———
Globorotalia truncatulinoides		———	———	— ? —
Globigerina inflata		- - -	———	
Candeina nitida			———	- - - - -
Globigerinoides sacculifera			———	———
Globorotalia menardii			———	———
Globigerinoides sp.			———	———
Globigerinoides conglobata			———	———
Globorotalia tumida			- - - - -	- - - - -
Globorotalia hirsuta			- - - - -	- - - - -
Pulleniatina obliqueloculata				———
Globigerinella sp.				———
Sphaeroidinella dehiscens				———
Globigerina conglomerata				———
Hastigerinella digitata			?	- - - - -

* Ecology of living Planktonic Foraminifera in the North and Equatorial Pacific Ocean, by J S. Bradshaw Contributions from the Cushman Foundation for Foraminiferal Research vol. X, part. 2, April, 1959

IV.- MORFOLOGIA Y TERMINOLOGIA

TESTA.- Concha o caparazón secretado por el animal; en foraminíferos planctónicos, está constituída por paredes dobles de calcita radial hialina; es perforada y puede tener quillas.

FORMA Y DESARROLLO DE LA TESTA.- Las testas de los foraminíferos planctónicos puede ser: umbilicadas y no umbilicadas, características sujetas a la disposición de las cámaras.

TESTAS UMBILICADAS.- Con ombligo amplio o cerrado, localizado sobre el eje de enrollamiento, donde se unen las cámaras de la vuelta final; puede observarse sobre uno, o en ambos lados de la testa. Se subdividen en:

Planispiral biumbilicada.- Con enrollamiento simétrico, ambos lados umbilicados. Ej.: Globigerinelloides algeriana Cushman y Ten Dam. (Lám. I, fig. 1).

Planispiral evoluta.- Las vueltas del enrollamiento son visibles en ambos lados. Ej.: Hastigerina siphonifera (d'Orbigny). (Lám. I, fig. 2).

Planispiral involuta.- Unicamente la vuelta final es visible en cada lado. Ej.: Hastigerina pelagica (d'Orbigny). (Lám. I, fig 3).

Trocospiral.- Testa asimétrica con todas las cámaras visibles en el lado espiral. Ej.: "Globigerinoides" higginsi Bolli. (Lám. I, fig. 4).

Trocospiral biconvexa.- Lado espiral y umbilical, convexos. Ej.: Globorotalia tumida (Brady). (Lám. I, fig. 5).

Trocospiral espiroconvexa.- Lado espiral convexo; lado umbilical plano a cóncavo. Ej.: Globotruncana contusa (Cushman). (Lám. I, fig. 6).

Trocospiral umbilo-convexa.- Lado umbilical convexo, lado espiral plano a cóncavo. Ej.: Globorotalia truncatulinoides (d'Orbigny). (Lám. I, fig. 7).

Enrollamiento biserial.- Es una modificación del desarrollo planispiral, en el cual alternan las cámaras en forma biserial. Este tipo de enrollamiento es característico de la familia Cassidulinidae, que es bentónica, pero también se le encuentra en el genero planctónico Cassigerinella chipolensis (Cushman y Ponton). (Lám. I, fig. 8).

TESTAS NO UMBILICADAS.- Carecen de ombligo. Se subdividen en:

Estreptospiral.- Este tipo de testas es una modificación de las trocospirales, pero el plano de enrollamiento cambia continuamente, y en consecuencia varía también el eje, por lo que no se forma ombligo. Ej.: Pulleniatina obliqueloculata (Parker y Jones). (Lám. I, fig. 9).

Globular.- La testa está formada por el desarrollo de la cámara final, como en Orbulina universa (d'Orbigny); puede resultar también por el aumento rápido de las últimas cámaras que engloban a las iniciales, como en Globigerinatheka barri Brönnimann. (Lám. I, figs. 10 y 11).

En los géneros de la familia Heterohelicidae, el desarrollo y forma de la testa es como sigue:

Triserial.- Testa compuesta en series de tres, desde su porción inicial, hasta el estado adulto. Ej.: Guembelitria cretacea (Cushman). (Lám. II, fig. 1).

Trocospiral elevada.- Cámaras con una espira trocospiral elevada; en ejemplares tipos con 4 cámaras infladas por vuelta. Ej.: Gubkinella asiatica Suleymanov. (Lám. II, fig. 2).

Triserial-multiserial.- Porción inicial triserial en el adulto, después se desarrollan varias cámaras. Ej.: Guembelitriella graysonensis Tappan. (Lám. II, fig. 3).

Con vuelta de 3 cámaras-biserial.- Primera porción con una sola vuelta de 3 cámaras infladas, seguida por un estadío biserial. Ej.: Woodringina claytonensis Loeblich y Tappan. (Lám. II, fig. 4).

Acampanada.- Se observa en ejemplares de la subfamilia Heterohelicinae Ej.: Chiloguembelina crinita (Glaessner). (Lám. II, fig. 5).

Flabeliforme.- En forma de abanico, este tipo de testa se encuentra en la subfamilia Heterohelicinae. Ej.: Planoglobulina acervulinoides (Egger). (Lám. II, fig. 6)

Planispiral - biserial.- Porción inicial en espiral plana, desarrollando después cámaras dispuestas en forma biserial. Ej.: Heterohelix globulosa (Ehrenberg). (Lám. II, fig. 7).

Biserial.- Cámaras arregladas biserialmente, con tendencia a torcerse, se observa en formas de la subfamilia Heterohelicinae. Ej.: Chiloguembelina wilcoxensis (Cushman y Ponton) (Lám. II, fig. 8).

Biserial - uniserial.- Testa en la que se observa inicialmente un desarrollo biserial seguido de una sola serie de cámaras. (Reducción de series de cámaras). Ej.: Bifarina nodosaria (White). (Lám. II, fig. 9).

Trocospiral o planispiral con proliferación de cámaras.- Porción inicial trocospiral o planispiral, desarrollando posteriormente un mayor número de cámaras, éstas generalmente se observan en la porción final de la testa. Ej.: Racemiguembelina fructicosa (Egger). (Lám. II, fig. 10).

CAMARAS.- Se da el nombre de cámara a cada una de las partes o celdillas que forman la testa de los foraminíferos, las cuales quedan separadas unas de otras por los tabiques o "septos". A las primeras cámaras que se forman se les llama cámaras iniciales, y el tipo de desarrollo de ellas en conjunto determina generalmente la forma de la testa. Existen excepciones como Heterohelix, Planoglobulina, Bifarina, Hastigerina, etc. En los globigerináceos la forma de las cámaras puede ser:

Cónico - angulares.- Cámaras infladas en forma de cono, con margen angular. Ej.: Globorotalia truncatulinoides (d'Orbigny). (Lám. III, fig. 1).

Rombo - angulares.- Cámaras romboidales, angulosas, como en Rotalipora greenhornensis (Morrow). (Lám. III, fig. 2).

Trunco - angulares.- Cámaras infladas con margen truncado y quilla angular. Ej.: Globotruncana arca (Cushman). (Lám. III, fig. 3).

Ovaladas.- Cámaras moderadamente infladas de forma oval. Ej.: Ticinella roberti (Gandolfi). (Lám. III, fig. 4).

Hemisféricas.- Cámaras con un lado inflado y el opùesto plano. Ej.: Globotruncana helvetica Bolli. (Lám. III, fig. 5).

Esféricas.- Cámaras esféricas individualizadas, como en Globigerina bulloides d'Orbigny. (Lám. III, fig. 6).

Claviformes.- Cámaras alargadas e infladas en la parte final, como en Clavigerinella akersi Bolli, Loeblich y Tappan. (Lám. III, fig. 7).

Tubulo - espinadas.- Cámaras con prolongaciones radiales que terminan con unas extensiones huecas o tubulo - espinadas. Ej.: Schackoina cenomana (Schacko). (Lám. III, fig. 8).

Alargadas radialmente.- Esta forma de cámaras se observa por ejemplo en Plummerita hantkeninoides Brönnimann. (Lám. III, fig. 9).

ABERTURAS: En la testa pueden existir aberturas exteriores y aberturas que comunican entre sí las cámaras. La forma y la posición varían mucho de unos géneros a otros y pueden presentar diversas modificaciones. Se dividen en:

Abertura Primaria.- Es la abertura principal que se encuentra en la testa y tiene las siguientes posiciones:

Umbilical.- Aberturas en la cámara final, cuya posición está en el ombligo; se le encuentra sobre el lado umbilical de las formas trocospirales. Ej.: Globigerina bulloides d'Orbigny. (Lám. IV, fig. 1).

Extraumbilical - umbilical.- Se extiende desde el ombligo, sobre el margen de la cámara final, hacia la periferia. Ej.: Globorotalia tumida (Brady). (Lám. IV, fig. 2).

Ecuatorial.- Es característica de las formas planispirales; es interiomarginal simétrica y se le encuentra en la cámara final; puede ser alargada como en Clavigerinella akersi Bolli, Loeblich y Tappan; trirradial como en Hantkenina alabamensis Cushman, y en arco bajo como en Hastigerina pelagica (d'Orbigny). (Lám. IV, figs. 3, 4 y 5).

Espiro - umbilical.- Abertura interiomarginal extendiéndose desde el ombligo a la periferia y finalmente sobre el lado espiral. Ej.: Hastigerinella digitata (Rhumbler). (Lám. IV, fig. 6).

Interiomarginal en la base de la última cámara. Se observa como un arco en la posición ya mencionada. Ej.: Guembelitria cretacea Cushman. (Lám. V, fig. 1).

Interiomarginal Simétrica.- Arco que se encuentra en la base de la última cámara en las formas biseriales. Ej.: Heterohelix globulosa Ehrenberg. (Lám. V, fig. 2).

Terminal.- Se observa en las formas uniseriales; es casi circular y puede, o nó tener un cuello corto. Ej.: Bifarina nodosaria (White). (Lám. V, fig. 3).

Aberturas Secundarias.- Pequeñas aberturas que se desarrollan además de la abertura primaria y en formas muy especializadas, pueden reemplazar a la abertura primaria. En este tipo se incluyen las siguientes:

Relícticas.- En la familia Planomalinidae, se originan en las porciones umbilicales de la abertura ecuatorial que al no estar cubierta por las cámaras sucesivas, permanecen en forma de pequeñas hendeduras radiales alrededor de los ombligos; estas

Aberturas se pueden observar, porque los labios aberturales prominentes quedan visibles. Ej.: Globigerinelloides eaglefordensis (Moreman). (Lám. VI, fig. 1).

Suplementarias.- Pueden presentarse además de la abertura primaria, por lo cual son independientes de la abertura principal y en algunos casos pueden reemplazarla completamente como en Cribrohantkenina inflata (Howe). Se pueden encontrar ejemplares con la abertura primaria ecuatorial y las suplementarias areales. (Lám. VI, fig. 2).

Areales.- Aberturas suplementarias múltiples areales.- Se desarrollan por ejemplo en Cribrohantkenina, En algunos ejemplares de este género se encuentran al mismo tiempo la abertura primaria, ecuatorial y las aberturas suplementarias areales, siendo esto último un carácter secundario.

Suplementarias Suturales.- Pequeñas aberturas individualizadas; pueden ser una por sutura, como en Rotalipora, o múltiples aberturas en las suturas, como en Candeina. En ocasiones están restringidas al lado espiral, como en Truncorotaloides, o en el lado umbilical como en Rotalipora, o presentarse en ambos lados como en Candeina. (Lám. VI, figs. 3, 4 y 5). Por último, ese tipo de aberturas pueden estar muy cerca de la sutura en forma de zig-zag de las formas biseriales. Ej.: Pseudoguembelina excolata (Cushman). (Lám. VI, fig. 6).

Aberturas Accesorias.- Las aberturas accesorias no existen en las primeras cámaras, se les encuentra en o debajo de las estructuras accesorias llamadas ámpula "Bulla" y tégula "tegilla" y se denominan infralaminares e intralaminares. Los términos "Ampula" y "Tégula", se introducen con el fin de castellanizar los de "Bulla y Tegilla". Como se está más familiarizado con los últimos términos citados, se utilizaron para facilitar la identificación.

Aberturas Accesorias Infralaminares.- Se da este nombre a la o las aberturas que están al lado de los márgenes y abajo de las estructuras accesorias. Ej.: Catapsydrax dissimilis Cushman y Bermúdez. (Lám. VI. fig. 7).

Aberturas Accesorias Intralaminares.- Aberturas generales múltiples, las cuales perforan las estructuras accesorias. Ej.: Rugoglobigerina rugosa (Plummer). (Lám. VI, fig. 8).

Estructuras Accesorias.- Se incluyen como tales: cámaras secundarias, camarillas, laminillas, etc., y están relacionadas directamente con la abertura, y pueden considerarse como modificaciones aberturales.

MODIFICACIONES ABERTURALES.

Labio Abertural Simple.- Es la forma más sencilla de las modificaciones aberturales; presenta formas variadas, así puede ser angosto y alargado, corto y espatulado. Ej.: Globorotalia tumida (Brady). (Lám. VII, fig. 1).

Rebordes Aberturales Laterales.- Son semejantes al labio abertural de las formas trocospirales, se localizan en ambos lados de las aberturas alargadas. Ej.: Hantkenina alabamensis Cushman. (Lám. VII, fig. 2).

Dientes Umbilicales.- Son modificaciones triangulares del labio abertural en las formas con abertura umbilical. Ej.: Globoquadrina altispira altispira (Cushman y Jarvis). (Lám. VII, fig. 3).

Rebordes de las Cámaras.- Extensiones marginales a lo largo del margen basal de las cámaras, las cuales tienden a ocultar las suturas y, en ocasiones, a cubrir la abertura umbilical. Ej.: Sphaeroidinella dehiscens (Parker y Jones). (Lám. VII, fig. 4).

Tégula o "Tegilla".- Estructura frágil que cubre el ombligo; se observa en la familia Globotruncanidae, Ej.: Trinitella scotti (Brönnimann). (Lám. VII, fig. 5).

Ampula o "Bulla".- Estructura en forma de vesícula o ampolla que cubre parcial o totalmente la abertura primaria, o las secundarias; se relacionan sólo con la abertura, y no con las cámaras principales. Se aprecian en ella una o más aberturas accesorias marginales. Este tipo de estructura se observa en la subfamilia Catapsydracinae y se presenta en diferentes posiciones, de acuerdo con las cuales se les denominan:

Ampula o "Bulla" Umbilical.- Cubre el ombligo. Ej.: Catapsydrax dissimilis (Cushman y Bermúdez). (Lám. VII, fig. 6).

Ampulas Suturales o "Bulla" Sutural.- Cubren las aberturas secundarias; se les observa siempre en las suturas. Ej.: Globigerinatheka barri Brönnimann. (Lám. VII,, fig. 7)

Ampula o "Bulla" Sutural Umbilical.- En este caso cubre el ombligo y la abertura que se encuentra en él, extendiéndose a lo largo en parte de las suturas. Ej.: Tinophodella ambitacrena Loeblich y Tappan, (Lám. VII, fig. 8).

Ampulas Areales o "Bulla" Areal.- Estas cubren las múltiples aberturas areales, Ej.: Globigerinatella insueta Cushman y Stainforth. (Lám. VII, fig. 9).

ORNAMENTACION.

La ornamentación de la superficie de la testa, es importante desde el punto de vista específico, y la terminología usada en las descripciones es la siguiente.

Lisa.- Sin ornamentación, Ej.: Candeina nitida d'Orbigny. (Lám. VIII, fig. 1).

Reticulada.- En forma de red; puede dar la apariencia de un panal. Ej.: Subbotina triloculinoides (Plummer). (Lám. VIII, fig. 2).

Rugosa.- Ornamentación irregular y tosca que como su nombre lo dice, presenta rugosidades. Ej.: Rugoglobigerina rugosa (Lám. VIII, fig. 3).

Granulosa.- En estas testas se observan pequeñas protuberancias, que comúnmente se presentan sobre las quillas, o en la pared de las cámaras. Ej.: Globotruncana arca (Cushman). (Lám. VIII, fig. 4).

Punteada.- La pared de la testa tiene depresiones pequeñas, circulares, en su superficie. Ej.: Sphaeroidinella dehiscens (Lám. VIII, fig. 5).

Espinosa.- Con espinas macizas y finas, generalmente alargadas. Ej.: Hastigerinella digitata (Rhumbler). (Lám. VIII, fig. 6). También las espinas pueden ser cortas y cubrir toda la testa, o sólo parte de ella. Ej.: Truncorotaloides topilensis (Cushman). (Lám. VIII, fig. 7).

Híspida.- En este caso también hay espinas cortas y muy finas impartiendo a la testa aspecto velloso. Ej.: Globigerina sellii (Borsetti). (Lám. VIII, fig. 8).

Costillas longitudinales.- Rebordes prominentes que se presentan sobre la superficie de algunos géneros planctónicos. Ej.: Pseudoguembelina excolata (Cushman). (Lám. VIII, fig. 9).

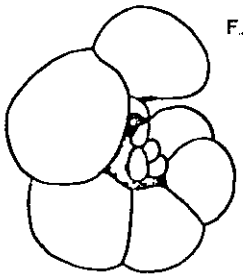
Estrias.- Acanaladuras finas. Ej.: Heterohelix navarroensis Loeblich. (Lám. VIII, fig. 10).

Quilla o Carina.- Reborde plano, anguloso, truncado, que circunda la periferia de la testa, puede ser grueso o fino y en ocasiones presenta granulaciones, observándose en las familias Globorotaliidae, Globotruncanidae, Planomalinidae y Rotaliporidae. Se encuentran ilustradas en las Láminas: I, figs. 5, 6, 7. III, figs. 1, 2, 3, 5. IV, fig. 2. VI, fig. 4. VII, fig. 1, VIII, fig. 4).

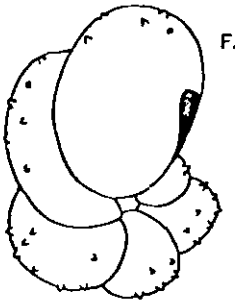
TESTAS UMBILICADAS


F.1

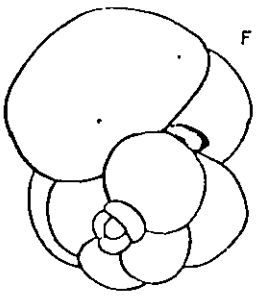
Planispiral biumbilicada Globigerinelloides algeriana Cushman y Ten Dam.


F.2

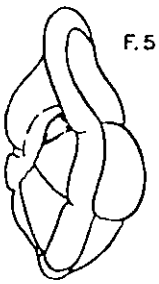
Planispiral evoluta Hastigerina siphonífera (d'Orbigny)


F.3

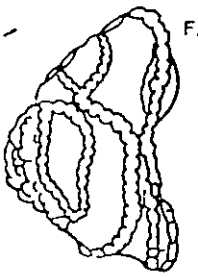
Planispiral involuta Hastigerina pelagica (d'Orbigny)


F 4

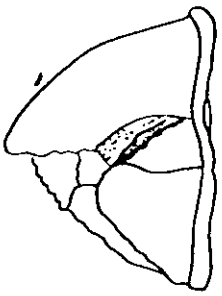
Trocospiral "Globigerinoides" higginsi Bolli


F.5

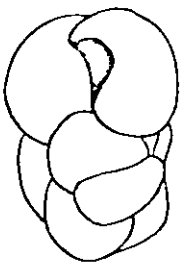
Trocospiral biconvexa Globorotalia tumida (Brady)


F. 6

Trocospiral espiro-convexa Globotruncana contusa (Cushman)

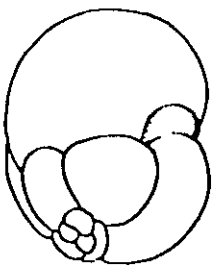

F. 7

Trocospiral umbilo-convexa, Globorotalia truncatulinoides (d'Orbigny)

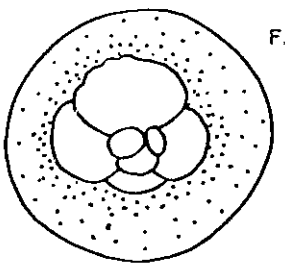

F 8

Enrollamiento biserial Cassigerinella chipolensis (Cushman y Ponton)

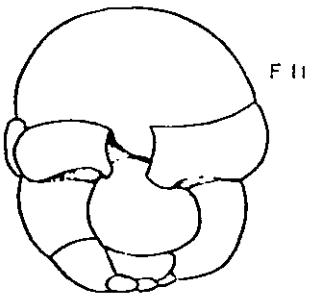
TESTAS NO UMBILICADAS


F 9

Estreptospiral Pulleniatina obliquelocuiata (Parker y Jones)

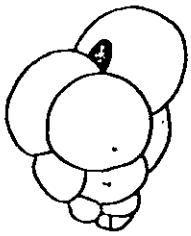

F.10

Globular Orbulina universa (d' Orbigny)


F 11

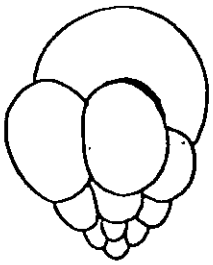
Globular Globigerinatheka barri Brönnimann.

LAMINA-I FORMA Y DESARROLLO DE LA TESTA



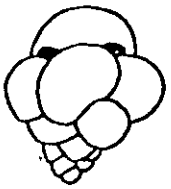
F. 1

Triserial
Guembelitria cretácea
(Cushman)



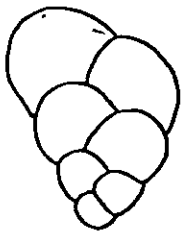
F. 2

Trocospiral elevada
Gubkinella asiática
Suleymanov.



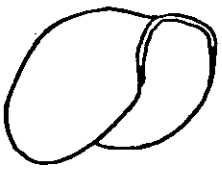
F. 3

Triserial-multiserial
(proliferación de cámaras)
Guembelitriella graysonensis
Tqppan.



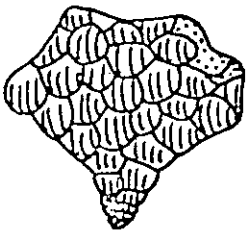
F. 4

Con vuelta de tres
cámaras-biserial
Woodringina claytonensis Loeblich y Tappan



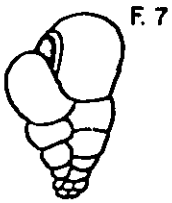
F. 5

Acampanada
Chiloguembelina crinita (Glaessner)



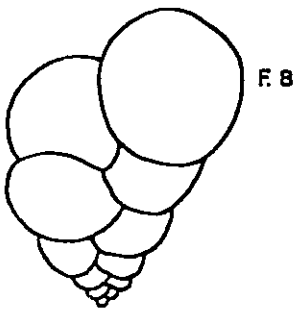
F. 6

Flabeliforme
proliferación de cámaras
Planoglobulina acervulinoides
(Egger)



F. 7

Planispiral-biserial
Heterohelix globulosa (Ehrenberg)

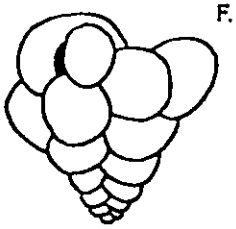


F. 8

Biserial
Chiloguembelina wilcoxensis
(Cushman y Ponton)

F. 9

Biserial-uniserial
(reducción de cámaras) Bifarina nodosaria (White)

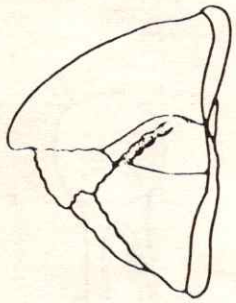


F. 10

Trocospiral o planispiral con proliferación de cámaras Racemiguembelina fructicosa (Egger)

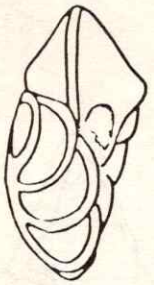
LAMINA II FORMA Y DESARROLLO DE LA TESTA

F. 1



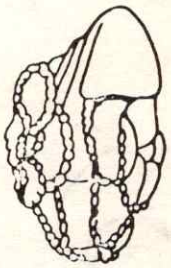
Cónico - angulares
Globorotalia truncatulinoides
(d'Orbigny)

F. 2



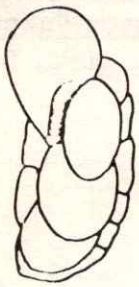
Rombo - angulares
Rotalipora greenhornensis (Morrow)

F. 3



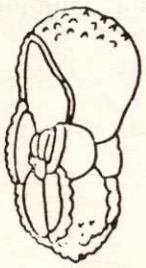
Trunco-angulares
Globotruncana arca
(Cushman)

F. 4



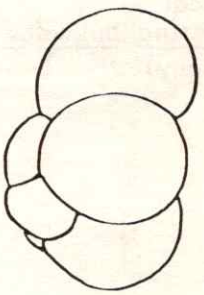
Ovaladas
Ticinella roberti
(Gandolfi)

F. 5



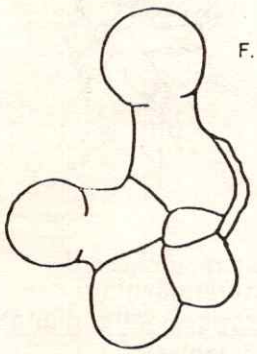
Hemisféricas
Globotruncana helvetica
Bolli

F. 6



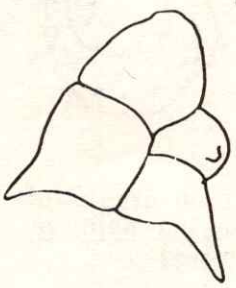
Esféricas
Globigerina bulloides
d'Orbigny

F. 7



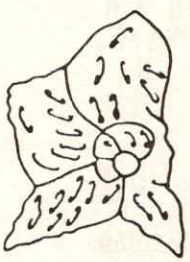
En forma de clavas
Clavigerinella akersi
Bolli, Loeblich y Tappan

F. 8



Tubulo-espinadas
Schackoina cenomana
(Schacko)

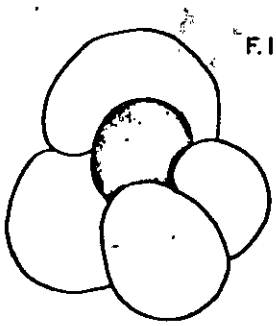
F. 9



Alargadas radialmente
Plummerita hantkeninoides
Brönnimann

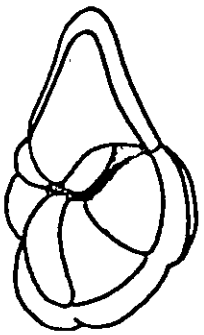
LAMINA III MORFOLOGIA DE LAS CAMARAS

ABERTURAS PRIMARIAS



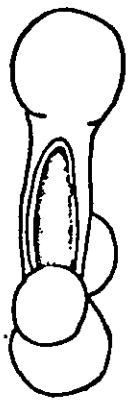
F. 1

Umbilical
Globigerina bulloides
(d'Orbigny)



F. 2

Extraumbilical umbilical
Globorotalia tumida
(Brady)

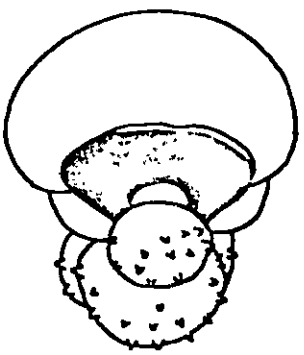


F. 3

Ecuatorial alargada
Clavigerinella akersi
Bolli, Loeblich y Tappan

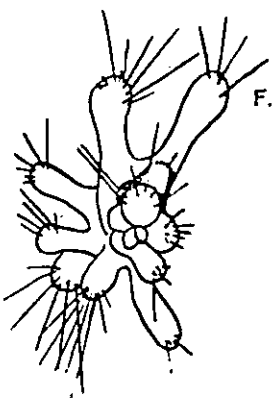
F. 4

Ecuatorial
trirradial
Hantkenina
alabamensis
(Cushman)



F. 5

Ecuatorial-arco bajo
Hastigerina pelagica
(d'Orbigny)



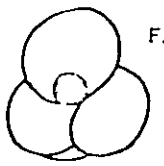
F. 6

Espiro-umbilical
interiomarginal
Hastigerinella digitata
(Rhumbler)

LAMINA IV

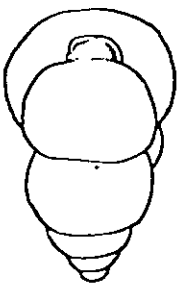
ABERTURAS DE LA TESTA

ABERTURAS PRIMARIAS



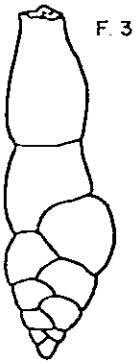
F. 1

Arco interiomarginal en la base de la última cámara Guembelitria cretácea (Cushman)



F. 2

Arco interiomarginal simétrico en la base de la última cámara. Heterohelix globulosa. (Ehrenberg).

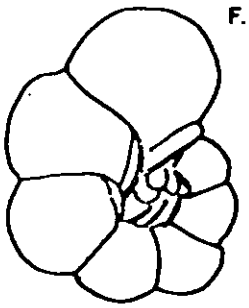


F. 3

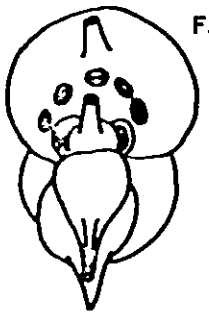
Terminal con cuello Bifarina nodosaria (White)

LAMINA V ABERTURAS DE LA TESTA

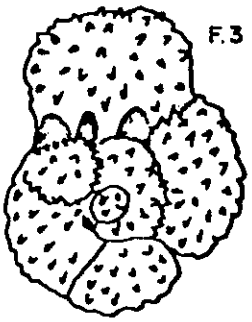
ABERTURAS SECUNDARIAS


F.1

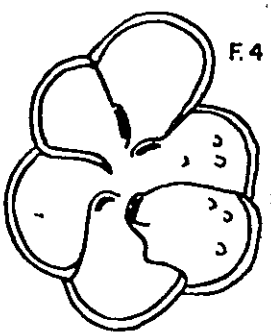
Aberturas relícticas Globigerinelloides eagleforderisis (Moreman)


F. 2

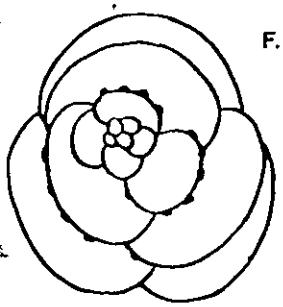
Aberturas suplementarias areales. Cribrohantkenina inflata (Howe)


F.3

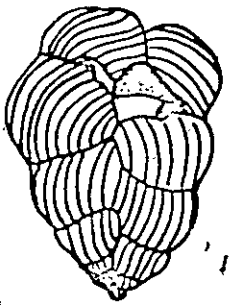
Aberturas suturales individuales en el lado espiral. Truncorotaloides rohri Bronnimann y Bermudez


F.4

Aberturas suturales individuales en el lado umbilical. Rotalipora cushmani (Morrow).

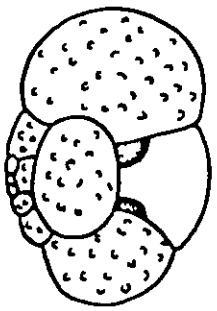

F. 5

Aberturas multiples suturales. Candeina nitida d'Orbigny.

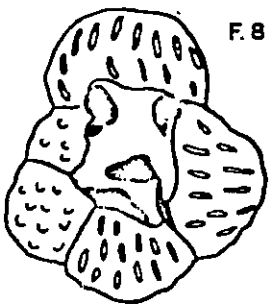

F. 6

Aberturas secundarias suturales cerca de la sutura en zigzag en formas biseriales Pseudoguembelina excolata (Cushman)

ABERTURAS ACCESORIAS

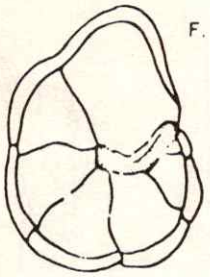

F.7

Aberturas infralaminares Catapsydrax dissimilis (Cushman y Bermúdez)


F.8

Aberturas infralaminares e intralaminares. Rugoglobigerina rugosa (Plummer)

LAMINA VI ABERTURAS DE LA TESTA

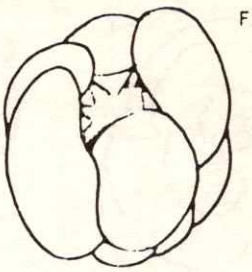


F. 1

Labio abertural simple
Globorotalia tumida
(Brady)

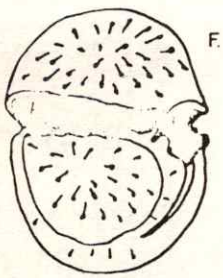
F. 2

Rebordes aberturales laterales
Hantkenina alabamensis
Cushman.



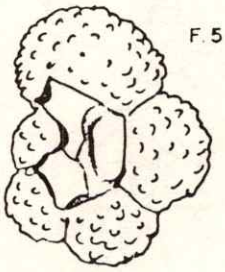
F. 3

Dientes umbilicales
Globoquadrina altispira altispira (Cushman y Jarvis)



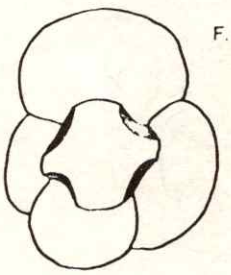
F. 4

Rebordes de las cámaras
Sphaeroidinella dehiscens
(Parker y Jones)



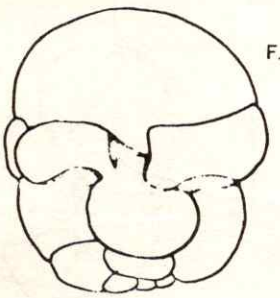
F. 5

Tegilla
Trinitella scotti
(Brönnimann)



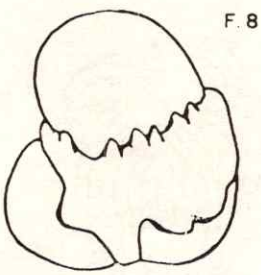
F. 6

Bulla umbilical
Catapsydrax dissimilis
(Cushman y Bermúdez)



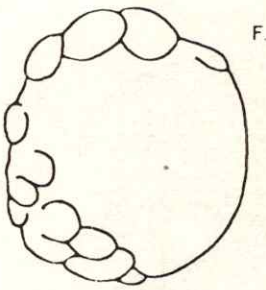
F. 7

Bulla sutural
Globigerinatheka barri
Brönnimann



F. 8

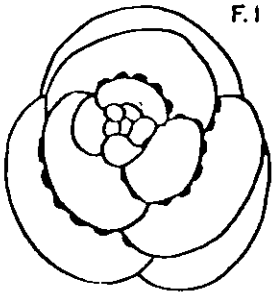
Bulla sutural umbilical
Tinophodella ambitacrena
Loeblich y Tappan.



F. 9

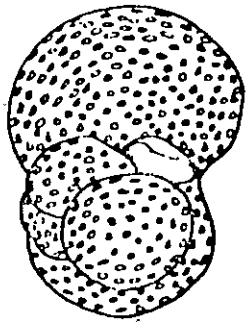
Bulla areal
Globigerinatella insueta
Cushman y Stainforth.

MODIFICACIONES ABERTURALES EN FORAMINIFEROS PLANCTONICOS
LAMINA VII



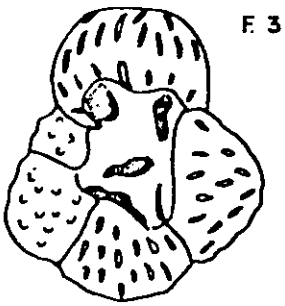
F. 1

Lisa
Candeina nítida
d' Orbigny



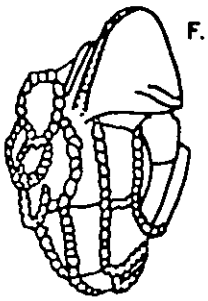
F. 2

Reticulada
Subbotina triloculinoides
(Plummer)



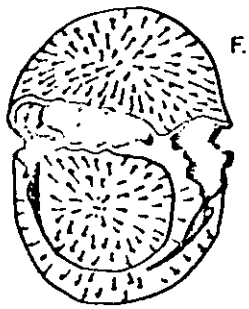
F. 3

Rugosa
Rugoglobigerina rugosa
(Plummer)



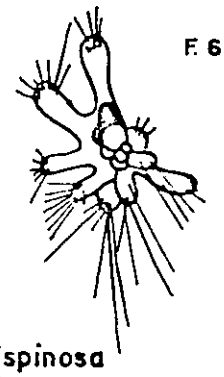
F. 4

Granulosa
Globotruncana arca
(Cushman)



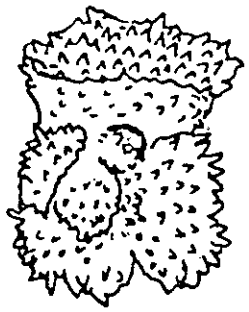
F. 5

Punteada
Sphaeroidinella dehiscens
(Parker y Jones)



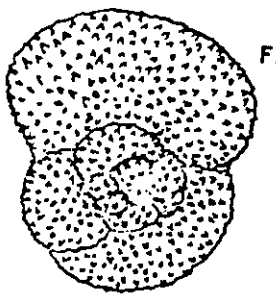
F. 6

Espinosa
Hastigerinella digitata
(Rhumbler)



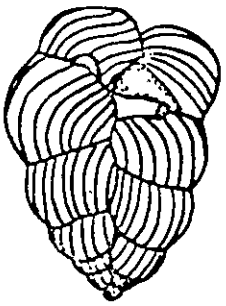
F. 7

Espinosa
Truncorotaloides topilensis
(Cushman)



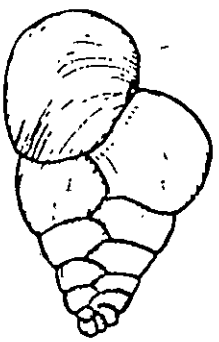
F. 8

Hispida
Globigerina sellii
(Borsetti)



F. 9

Costillas longitudinales
Pseudoguembelina excolata (Cushman)



F. 10

Estrías
Heterohelix navarroensis
Loeblich.

SUPERFICIE.-ORNAMENTACION DE FORAMINIFEROS PLANCTONICOS

LAMINA VIII

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Problems in Paleogene and Neogene correlations based on planktonic foraminifera*

ABSTRACT

Paleogene and Neogene world-wide distribution patterns of planktonic foraminifera are discussed. Differences in environmental conditions, mainly changing water temperatures, are regarded as the principal factors controlling the occurrence and distribution of individual species. Species associations caused by natural barriers, such as the Isthmus of Panama, may also develop at similar latitudes. Furthermore, anomalous distribution patterns, resulting from the exclusion of certain species at the expense of others are also known within the same area.

As a result of all these differing species distributions numerous zonal schemes were proposed, some of which are herein shown on figures 1 and 6. Correlation problems that necessarily arise from this are discussed for a number of selected areas and sections. For the Paleogene, examples are discussed from the Caucausus-Crimea and eastern Mediterranean, where faunal differences are caused by climatic and facies changes. In the Neogene of the Caribbean-Atlantic and Indo-Pacific, different faunal developments and distribution patterns may occur at similar latitudes. A good example of temporary exclusion of certain species is found within the Caribbean, where during the presence of *Globorotalia miocenica* Palmer, *G. exilis*, and *G. pertenuis* Beard in the Middle Pliocene, *Pulleniatina* sp. and to a large degree also *Globorotalia menardii* (d'Orbigny) have disappeared, to return only after the extinction of the first named group of species.

INTRODUCTION

Planktonic organisms (foraminifera, radiolaria, calcareous nannoplankton) are characterized by a fast rate of evolutionary development, wide geographic distribution, and abundance in deep-water marine sediments. All these factors have proved useful in the application of these organisms to the purposes of a world-wide biostratigraphy.

Among these organisms, planktonic foraminifera were the first to be studied in detail for biostratigraphic purposes. However, detailed investigations in various parts of the world have shown that the composition of the planktonic foraminiferal faunas is by no means uniform. Their distribution is controlled by numerous factors which, in turn, affect their use in biostratigraphy. The subject of this paper is to discuss, using selected examples, the influence of chemical and physical factors on the composition and distribution of planktonic foraminiferal faunas. The principal factor is water temperature, as is clearly demonstrated in the distribution patterns of planktonic foraminifera in Recent water masses, where three main groups—tropical, temperate, and cold water—are distingished. The influence of climatic belts on planktonic foraminiferal distribution has become increasingly more pronounced throughout the Neogene. Though much less expressed, climatic belts also existed in the Paleogene and Cretaceous.

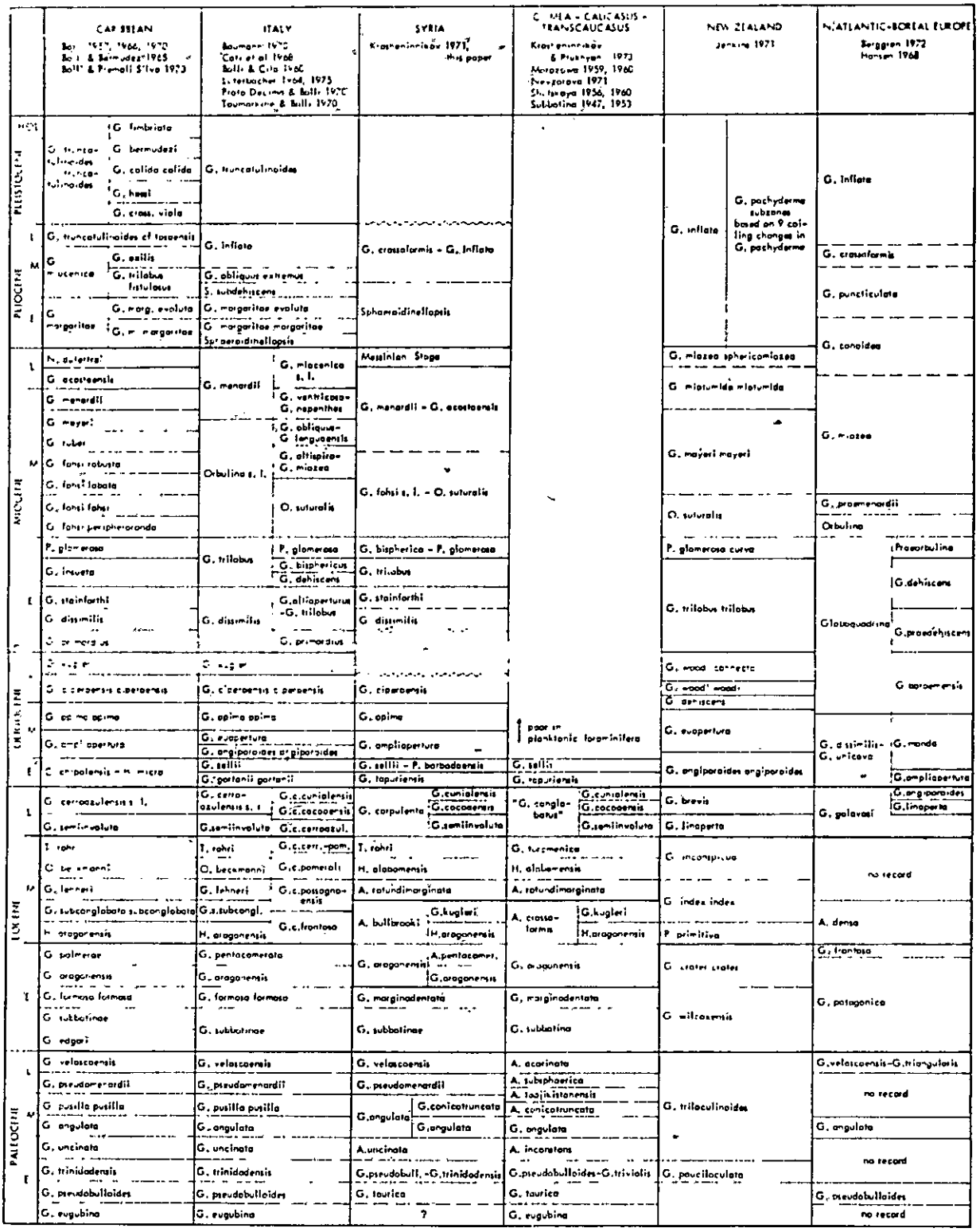
Additional chemical and physical factors influencing the presence and distribution of planktonic foraminifera in the ocean waters are salinity, turbidity, and currents. During or after deposition, the following influence their presence, composition, frequency, and preservation: selective dissolution, alterations in the process of diagenesis, rate of sedimentation, bioturbation, selective transportation, and reworking resulting in heterogeneous associations.

One of the prime prerequisites for the application of planktonic organisms to zonation is their correct identification. In clear-cut taxa there are few problems in this respect, but where the morphological characters are less pronounced or are subject to considerable variability, such as, for example, in *Globorotalia opima opima* Bolli or *Globigerina ampliapertura* Bolli, the species concept may readily be interpreted in too wide a sense, which, in turn, may affect the extent of the zone based on the taxa, and consequently lead to incorrect correlations.

The first Paleogene and Neogene planktonic foraminiferal zonal schemes established 20 to 30 years ago were based on tropical sequences,

*Paper presented at the 3rd Planktonic Conference, Kiel, West Germany, September, 1974.

micropaleontology, vol. 23, no. 4, pp. 436–452, october, 1977



TEXT-FIGURE 1

Comparison of zonal schemes: Caribbean; Italy; Syria; Crimea, Caucasus, Transcaucasus; New Zealand; North Atlantic, Boreal Europe.

mostly from the Caribbean area. Subsequently, those of the Paleogene, like those of the Cretaceous, were found to be applicable also as far north as the Alpine-Mediterranean area or, in part, even farther north. This is, however, not the case for the Neogene, in particular for its younger part, for the trend of faunal associations becomes progressively more and more selective and restricted latitudinally with the passage of time. Therefore, Neogene zonal schemes, for example those from the Mediterranean area, had at least partially to be based on taxa that are different from those applied in tropical areas. This has resulted in a proliferation of schemes as was for example demonstrated at the 1967 Mediterranean Neogene Conference in Bologna, where, for the Mediterranean area alone, some 17 different planktonic foraminiferal zonal schemes were discussed.

Zonal schemes based on planktonic foraminifera have been proposed from many different regions. Some of them, established for the Caribbean region, the Mediterranean region (Italy, Syria), the Crimea-Caucasus-Transcaucasus, New Zealand, and the North Atlantic-boreal Europe region are shown in text-figure 1. For the tropical, Mediterranean, and Crimea-Caucasus-Transcaucasus areas, there is generally good zonal correlation in the Paleogene; in New Zealand and the boreal areas of the North Atlantic and Europe, zonal resolution is less detailed and therefore offers less accurate correlation with the tropical and temperate regions. The close Neogene zonation of the Caribbean can be recognized only partially in the Pacific and temperate areas, and still more tentatively in the boreal ones.

Deep-water drilling in oceanic basins, performed by the Deep Sea Drilling Project (DSDP), has initiated a a new era in our knowledge of Cenozoic stratigraphy. The stratigraphy of sediments of oceanic basins is based largely on planktonic organisms because of the scarcity of benthonic forms. Thus, planktonic organisms have become the basis for world-wide biostratigraphic subdivision of fossil marine sediments both on land and in the oceans.

In the present paper, a number of examples of irregular or anomalous planktonic foraminiferal species distributions are presented, as are the resulting difficulties in applying established zonal schemes. The discussion is divided into a Paleogene part by V. A. Krasheninnikov and a Neogene part by H. M. Bolli. The Paleogene part deals with problems recognized in the Crimea and North Caucasus area, where different assemblages of planktonic foraminiferal species are found beside each other in the same zone. It also gives comparisons of planktonic foraminiferal distributions in the North Caucasus (South Armenia) and the Mediterranean (Syria) which reflect the influence of different climatic conditions (see text-figures 2, 3).

The influence of water temperature on the distribution of planktonic foraminifera in the Neogene is well known and has been discussed on several occasions, recently by Jenkins (1973), who recommended the recognition of three different zonal schemes, based on climatic belts. The Neogene problems discussed here are restricted to anomalous Pliocene-Pleistocene faunal distributions within one climatic belt. The occurrence of certain species in the Caribbean, Gulf of Mexico, and tropical Atlantic are compared with those found in the Indo-Pacific sections of Java and the Timor Trough.

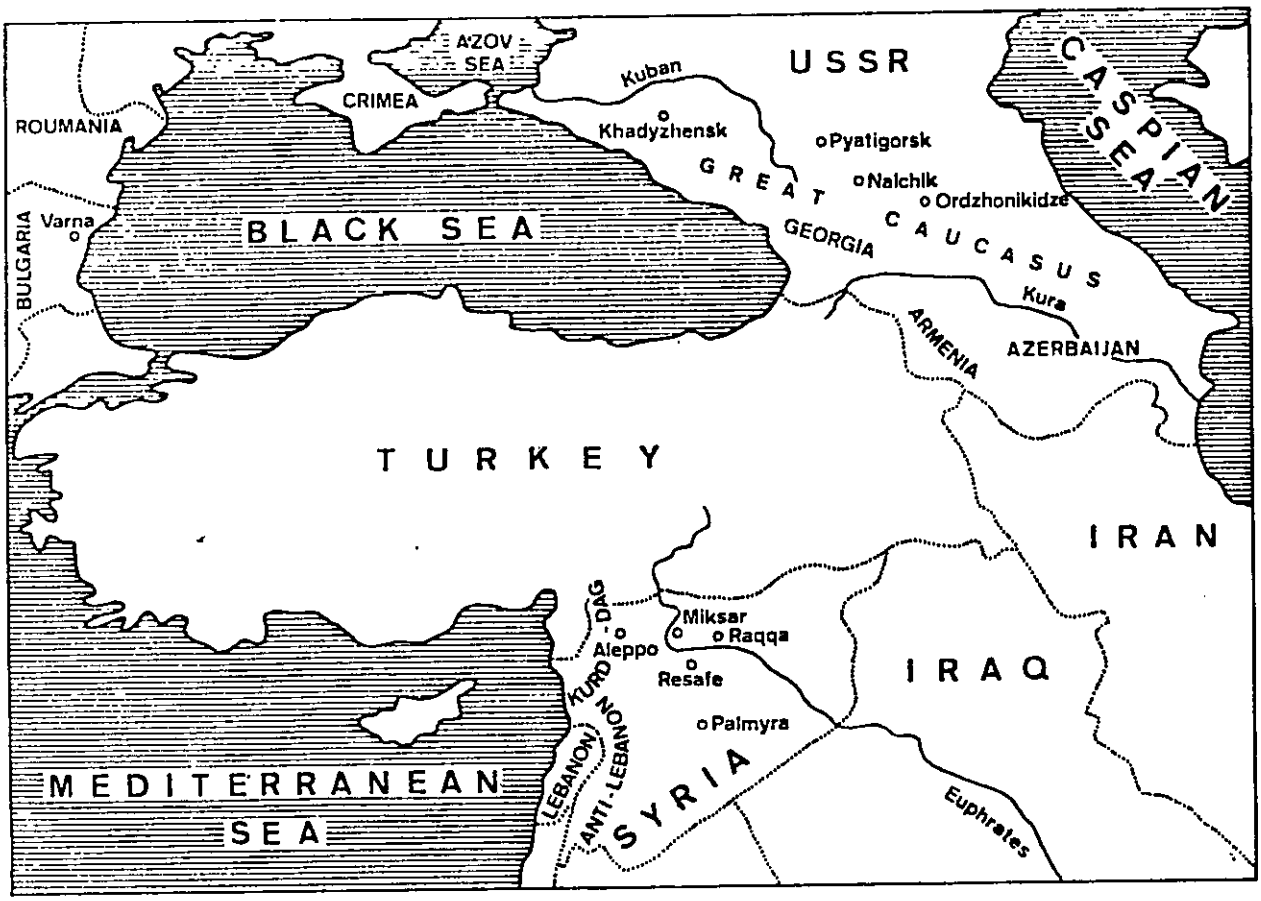
PALEOGENE (V.A.K.)

Paleogene deposits in the southern part of the USSR (the Crimean-Caucasian area) and the eastern Mediterranean (Syria) offer a great number of excellent examples of the influence of local facies conditions on the distribution of planktonic foraminifera.

a) Late Paleocene deposits assignable to the *Acarinina mckannai* and *A. acarinata* zones form a continuous band of outcrops along the slope of the North Caucasus. The lithological composition of deposits changes considerably from east to west.

To the east of the towns of Ordzhonikidze and Nalchik, the Late Paleocene sediments are composed of gray and greenish marls rich in abundant planktonic foraminifera. The *Acarinina mckannai* Zone is characterized by *Globorotalia pseudomenardii* Bolli, *G. elongata* Glaessner, *Acarinina mckannai* (White), *A. intermedia* Subbotina, *A. trichotrocha* (Loeblich and Tappan), *Globigerina velascoensis* Cushman, *G. nana* Chalilov, *G. pileata* Chalilov, *G. bacuana* Chalilov, *G. quadritriloculinoides* Chalilov, *G. chascanona* Loeblich and Tappan, and *G. aquiensis* Loeblich and Tappan. Especially representative of the *Acarinina acarinata* Zone are *A. acarinata* Subbotina, *A. intermedia*, *A. primitiva* (Finlay), *A. soldadoensis* (Bronnimann), *Globorotalia acuta* Toulmin, *G. apanthesma* Loeblich and Tappan, *Globigerina incisa* Hillebrandt, and *G. compressaformis* Chalilov; they are accompanied by some species of *Globigerina* and *Acarinina* ranging up from the *Acarinina mckannai* Zone. Calcareous nannoplankton is abundant.

The sediments become less calcareous toward the west. In the central Pre-Caucasus, in the vicinity of the towns of Minerainie Vody and Pyatigorsk, along the Kuban River, the Late Paleocene Goryachy Klyuch Formation and the lower part of the Abazinskaya Formation comprise dark noncalcareous clays with intercalations of sandstones, opokas (diatomites) and



TEXT-FIGURE 2
Crimean-Caucasian and Mediterranean areas, with some geographic names mentioned in text.

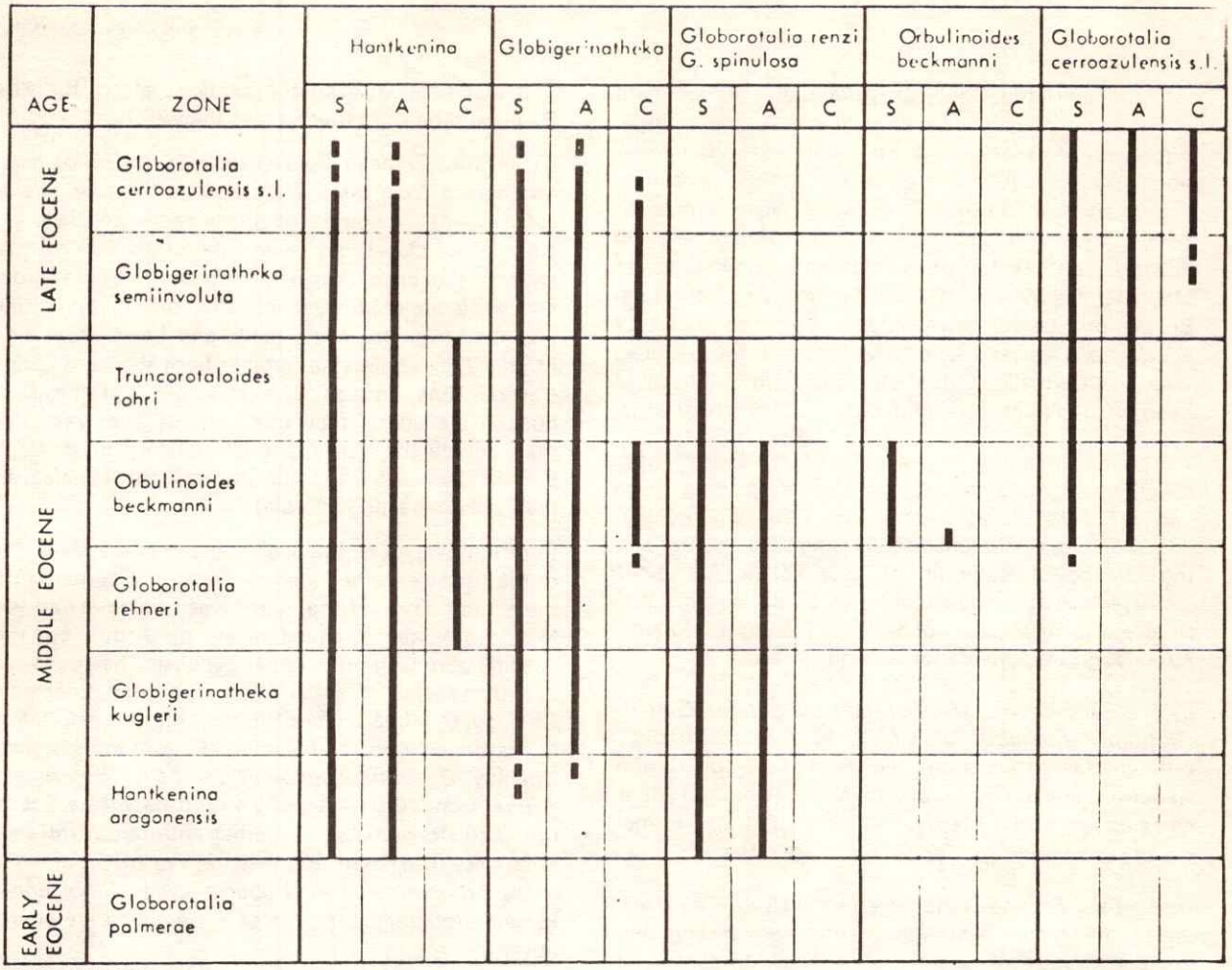
rare thin intercalations of slightly calcareous clays. Agglutinated and calcareous benthonic foraminifera are predominant among microorganisms. Planktonic foraminifera occur sporadically in intercbedded carbonate layers. They are represented by small specimens of *Globigerina* and *Acarinina*. *Globorotalia* are absent. Impoverished nannoplankton has been recorded from calcareous layers only.

In the western Pre-Caucasus, from Khadyzhensk to the Black Sea coast, the Late Paleocene is composed of flysch-type noncalcareous dark clays, claystones, and sandstones with numerous agglutinated foraminifera—primitive astrorhizids, ammodiscids, rheophacids, rhizamminids, hyperamminids, saccaminids. Planktonic foraminifera and nannoplankton are absent. Their place is taken by radiolaria.

Subbotina (1950) believed that the Late Paleocene sea basin of the central and western Pre-Caucasus was characterized by low temperature of bottom waters, which promoted the development of primitive agglutinated foraminifera. Cold surface currents existed in the extreme west, where radiolaria are predominant in the plankton. In the eastern Pre-Caucasus, the temperature of surface waters appeared to be rather high, as the sediments frequently abound with tests of *Globigerina* and *Acarinina; Globorotalia* are extremely rare.

b) In Syria, the Paleocene and Early Eocene (without its uppermost part) are represented by white, gray, and yellowish marls, soft clayey limestones, and greenish calcareous clays; their thickness reaches hundreds of meters. The distribution of clayey and calcareous sediments within these deposits is very irregular. They form large lens-shaped bodies replacing each other along the strike.

Clayey sediments are associated with depressions, stretching along the uplifts of the Lebanon and Anti-Lebanon in the west, Kurd-Dag in the northwest and Zagros in the northeast of Syria; within the intraplatform



TEXT-FIGURE 3
Ranges of some planktonic foraminiferal genera and species in Middle and Late Eocene of the Mediterranean (Syria), South Armenia (USSR) and the North Caucasus (USSR). S, Syria; A, South Armenia; C, North Caucasus.

depression of Palmyra they are related to minor local positive structures (Krasheninnikov, Ponikarov, and Razvalyaev, 1964). These uplifts were the likely source of clayey material.

Similar Paleocene and Early Eocene facies developments are also known in other countries of the Near East. Tromp (1943) introduced the terms Anatolian and Arabian facies for the clayey and carbonate facies, respectively, of the Paleocene and Early Eocene of the Near East. The specific composition of planktonic foraminifera in the Anatolian is rather different, for instance, from that of the Arabian facies of the Late Paleocene of Syria (*Globorotalia pseudomenardii* and *Globorotalia velascoensis* zones). Carbonate rocks of the Arabian facies contain abundant *Globorotalia*, *Acarinina*, and *Globigerina*, with representatives of *Globorotalia* strongly predominant [*G. velascoensis* Cushman, *G. occlusa* Loeblich and Tappan, *G. parva* Rey, *G. laevigata* (Bolli), *G pseudomenardii*, *G imitata* Subbotina, *G. convexa* Subbotina, *G. acuta*, *G. elongata*, *G. apanthesma*, *G. hispidicidaris* Loeblich and Tappan]. The test dimensions are maximal for the given species, with a thickened wall and strongly developed sculptural decorations in some species. Especially numerous is *Globorotalia velascoensis* with a high-conical test, deep umbilicus and ornamented septal sutures, peripheral margin, and umbilical chamber ends.

With increase in the clay content of the sediments, *i.e.*, transition to the Anatolian facies, the following changes take place in the paleocoenoses of planktonic forami-

nifera their number decreases gradually, predominant in number of specimens are *Acarinina* (*A. mckannai*; *A. intermedia*, *A. acarinata*, *A soldadoensis*, *A. primitiva*) and *Globigerina* (*G. nana*, *G. velascoensis*, *G. quadritriloculinoides*, *G. pileata*, *G. bacuana*, *G. aquiensis*, *G. compressaformis*); representatives of *Globorotalia* are less frequent. Tests of planktonic foraminifera are characterized by relatively small dimensions, sculptural decorations being only slightly developed. Tests of *Globorotalia velascoensis* become small, low-conical, with small umbilicus, thin keel, and hardly noticeable bead-shaped thickening of the umbilical chamber ends.

The change in morphology and dimension of planktonic foraminiferal tests in the sediments grading from calcareous to clayey types, show that the general impoverishment of planktonic foraminifera in clays and the change of the ratio of *Globorotalia*/*Acarinina*/*Globigerina* in these paleocoenoses cannot be attributed to selective dissolution of tests of planktonic foraminifera during sedimentation and diagenesis.

c) The Early Eocene (*Globorotalia subbotinae* Zone to *Globorotalia aragonensis s.l.* Zone) is represented by different facies types on the northern slope of the Caucasus and on its southern slope (Georgia); it is calcareous (marls, clayey limestones) in the former region and flysch and flyschlike in the latter.

In the Early Eocene carbonates of the North Caucasus, the following forms strongly predominate among very rich planktonic foraminiferal faunas—various species of conical and lens-shaped *Globorotalia*, including *G. caucasica* Glaessner, *G. aragonensis* Nuttall, *G. marksi* Martin, *G. lensiformis* Subbotina, *G. formosa* Bolli, *G. marginodentata* Subbotina, *G. subbotinae* Morozova, *G. aequa* Cushman and Renz, *G. wilcoxensis* Cushman and Ponton, and *G. planoconica* Subbotina. The deposits of *Globorotalia aragonensis s.l.* Zone along the Kheu River in the eastern Pre-Caucasus are extremely rich in conical *Globorotalia* (*G. caucasica*, *G. aragonensis*, and *G. marksi*).

In Georgia, along the Kura River, some thin intercalations of calcareous clays within flysch deposits barren of fossils contain rather rich assemblages of planktonic foraminifera; *Globorotalia*, however, is practically absent there. Foraminiferal assemblages consist of various species of *Acarinina* [*A. pseudotopilensis* Subbotina, *A. triplex* Subbotina, *A. camerata* Chalilov, *A. soldadoensis*, *A. interposita* Subbotina, *A. pentacamerata* (Subbotina)] and *Globigerina* (*G. pseudoeocaena* Subbotina, *G. inaequispira* Subbotina, *G. eocaenica* Terquem, *G. turgida* Finlay); their dimensions are rather small.

The distance between the sections along the Kheu River and the Kura River is less than 200 km.

d) In the Crimean-Caucasian area the *Globigerina turcmenica* Zone (an analogue of the *Truncorotaloides rohri* Zone) is composed of brown and dark gray calcareous claystones with abundant fish remains (Kuma horizon or Brown Formation). These brown sediments are recognizable in the area (mapping unit) and they separate white marls and limestones of the Middle Eocene Keresta horizon from the Late Eocene Belaya Glina horizon. The claystones of the Kuma horizon are surprisingly monotonous over vast areas that include the Varna Basin in eastern Bulgaria, the Crimea, the North Caucasus, the Transcaspian area, and the Transcausasus (Georgia).

Benthonic fauna is practically absent in the claystones of the *Globigerina turcmenica* Zone. This suggests that the bottom layer of the water was contaminated with H_2S. Planktonic foraminifera are numerous, but their specific composition is rather peculiar. They consist of various species of small *Globigerina* (*G. turcmenica* Chalilov, *G. praebulloides* Blow, *G. incretacea* Chalilov, *G. azerbaidjanica* Chalilov, *G. pseudocorpulenta* Chalilov, *G. subtriloculinoides* Chalilov), *Pseudohastigerina micra* (Cole), *Acarinina rugosoaculeata* Subbotina, and *Acarinina* sp., together with rare *Hantkenina longispina* Cushman. Representatives of *Globigerinatheka*, *Truncorotaloides*, *Globorotaloides*, *Globigerinita*, keeled *Globorotalia*, and large *Globigerina* are entirely absent.

In the northeastern part of Bulgaria (southern slope of the Dobrudja massif), the Middle and Late Eocene is composed of monotonous white marls and clayey limestones. Here deposits of the *Globigerina turcmenica* Zone contain not only the above-mentioned species of *Globigerina*, *Pseudohastigerina*, *Acarinina*, and *Hantkenina*, but also numerous *Truncorotaloides rohri* Brönnimann and Bermudez, *Globigerinatheka index* (Finlay), and *Globigerina pseudoeocaena* Subbotina together with rare *Truncorotaloides topilensis* (Cushman) and *Globorotalia spinulosa* Cushman. This association of planktonic foraminifera is very similar to that in the *Truncorotaloides rohri* Zone of the Mediterranean area.

These examples demonstrate the indirect relationship of planktonic foraminiferal composition to the sediment type, or the direct relationship to conditions of sedimentation. Unfortunately, very often one cannot say what bionomic factor causes the appearance of just this (but not another) assemblage of planktonic foraminifera. However, the influence of conditions of sedimentation on the composition of planktonic foraminifera is recognized; it is the cause of different paleocoenoses of

planktonic foraminifera that may occur within the same stratigraphic unit.

The following examples show the variability of planktonic foraminiferal assemblages in lithologically identical sediments.

e) Deposits of the uppermost part of the Early Eocene in Syria (*Acarinina pentacamerata* Subzone) are surprisingly monotonous throughout the area. They consist of white marls and limestones with intercalations and lenses of black and red-brown cherts; the thickness is up to 500 m. This formation of marls, limestones, and cherts of the late Early Eocene is widely developed in the countries of the Near East and North Africa.

In Syria this formation is a mapping unit and also a reflector in geophysical studies; it contains a number of mineral resources. Therefore, the stratigraphy and microfauna of deposits of the *Acarinina pentacamerata* Subzone have been studied rather thoroughly (over 2000 samples with microfauna). The abundant planktonic foraminifera are represented by *Globorotalia aragonensis* Nuttall, *G. caucasica*, *G. planoconica*, *G. quetra* Bolli, *Acarinina pentacamerata*, *A. aspensis* (Colom), *A. interposita*, *A. triplex*, *A. pseudotopilensis*, *A. soldadoensis*, *A. gravelli* (Bronnimann), *A. broedermanni* (Cushman and Bermudez), *Globigerina pseudoeocaena* Subbotina, *G. eocaena* Gumbel, *G. inaequispira* Subbotina, *G. eocaenica* Terquem, *G. prolata* Bolli, *G. senni* (Beckmann), and *Pseudohastigerina wilcoxensis* (Cushman and Ponton).

In deposits of the *Acarinina pentacamerata* Subzone along the Euphrates River, from Miksar to Raqqa, one can find, together with the above-mentioned species, *Globorotalia palmerae* (Cushman and Bermudez) (sometimes 100 to 150 specimens in one sample). Rare specimens of *G. palmerae* occur in synchronous deposits south of Resafe on the right bank of the Euphrates River. This species is absent in the rest of the territory of Syria.

Conical *Globorotalia* are distributed unevenly in the *Acarinina pentacamerata* Subzone. In a number of specimens they are never as numerous as *Acarinina* and *Globigerina*. Conical *Globorotalia* (*G. aragonensis*, *G. caucasica*) ara usually represented by tens of specimens in a sample of about 100 g.; occasionally, this number increases from 100 to 200, yet there are paleocoenoses without any *G. aragonensis* or *G. caucasica*.

The occurrence of *G. palmerae* is restricted to a narrow band along the Euphrates River. Conically shaped *Globorotalia* occur throughout Syria, but there may be strong variation in their number within a given section.

f) Deposits of the *Hantkenina alabamensis* Zone of Syria (an analogue of the *Orbulinoides beckmanni* Zone) are represented by monotonous white and pale-gray chalklike limestones and marls. These sediments are characterized by the following paleocoenoses of planktonic foraminifera:

Paleocoenosis with strong predominance of *Globigerinatheka index* combined with *G. kugleri* (Bolli, Loeblich and Tappan).

Paleocoenosis with *Orbulinoides beckmanni* which is rather diverse in specific composition, some *O. beckmanni* are however, always present. *Globigerinatheka* and *Orbulinoides* are frequently antagonists—an increase in the number of specimens of one is accompanied by a decrease in number of specimens of the other.

Paleocoenosis with *Hantkenina*; it is also diverse in its specific composition, but *H. alabamensis* Cushman and *H. dumblei* Weinzierl and Applin are always present.

Paleocoenosis with an enormous accumulation of large-sized *Globorotalia cerroazulensis* (Cole), all other species of planktonic foraminifera being relatively insignificant.

Paleocoenosis with strong predominance of *Truncorotaloides topilensis* and *T. rohri* Bronnimann and Bermudez.

Paleocoenosis consisting of abundant *Globigerina*—*G. pseudoeocaena*, *G. pseudovenezuelana* Blow and Banner, etc. Species of *Truncorotaloides*, *Orbulinoides*, *Globigerinathera*, and keeled *Globorotalia* may be almost entirely absent; for this reason, those assemblages resemble those of the Late Eocene.

Certainly, in deposits of the *Hantkenina alabamensis* Zone one can find assemblages of planktonic foraminifera which are intermediate in composition between those mentioned.

g) In the northern part of Syria, the Late Eocene is represented by soft, clayey limestones and marls. These sediments are also common in other regions of this country (Anti-Lebanon, Palmyrids), although there they are often replaced by detrital and algal limestones.

Marls and clayey limestones of the Late Eocene of the Anti-Lebanon and Palmyrids are characterized by extremely diverse planktonic foraminifera that allow a subdivision of the Late Eocene into the *Globigerapsis semiinvoluta*, *Globorotalia cerroazulensis cocoaensis*, and *Globigerina gortanii* zones. In the North Aleppo plateau of Syria, the foraminiferal paleocoenoses consist of abundant *Globigerina* [*G. corpulenta* (Subbotina), *G. pseudovenezuelana*, *G. tripartita* Koch, *G. galavisi* Bermudez, etc.], with practically no representatives of *Globigerinatheka*, *Hantkenina*, *Cribrohantkenina*, and the *Globorotalia cerroazulensis* group. Here, the zonal subdivision of the Late Eocene is difficult to apply.

In the Late Eocene marls and white limestones of the Crimea and North Caucasus the paleocoenoses of

planktonic foraminifera are characterized either by a predominance of *Globigerinatheka* [*G. tropicalis* (Blow and Banner), *G. index*], or large *Globigerina*.

It is more difficult to explain why there are several paleocoenoses of planktonic foraminifera in monotonous sediments of any stratigraphic subdivision, than to find the circumstances causing the existence of such paleocoenoses in lithologically different deposits. It is quite possible that not all physical-chemical (abiotic) factors of the environment determining the composition of biocoenoses of planktonic foraminifera are reflected in sediments. Also, it is difficult to evaluate the influences of biotic factors. At present one can, in the main, record the facts of distribution of assemblages of planktonic foraminifera in monofacies or polyfacies deposits of the same age. These observations are of paramount importance, as they make it possible to avoid errors in regional stratigraphic studies, and will help to work out a universal zonal scale.

A comparison of planktonic foraminiferal assemblages of the Paleogene of the Crimea-North Caucasus region, the intermediate region of Armenia (USSR), and the eastern Mediterranean (Syria) gives a good example of the influence of climatic belts on the distribution of planktonic foraminiferal genera and species. Two features characterize the anomalies of their distribution: 1) an improvement of the systematic composition of planktonic foraminifera in a northerly direction; 2) different stratigraphic ranges of some species and genera of planktonic foraminifera in the Paleogene. Following are some details of these anomalies:

1) The Paleogene deposits of Syria are characterized by typical tropical-subtropical planktonic foraminiferal assemblages, described from many countries of the Mediterranean, and the area of the Pacific, Indian, and Atlantic Oceans.

The territory of South Armenia belonged, in the Paleogene, to the "southern province," but it was probably the northern margin of that "southern province." Deposits of the Middle and Late Eocene and Early Oligocene of Armenia (facies conditions not favorable for microfaunas that prevailed in the Paleocene-Early Eocene) contain almost the same assemblages of planktonic foraminifera as those of the Mediterranean. However, some species are absent, such as *Clavigerinella jarvisi* (Cushman), *C. akersi* Bolli, Loeblich and Tappan, *Hantkenina dumblei*, *Globorotalia lehneri* Cushman and Jarvis, *G. bolivariana* (Petters), *Globigerina higginsi* (Bolli), and *Globigerinita echinata* (Bolli), some species are present sporadically and in small numbers of specimens only, such as *Orbulinoides beckmanni*, *Globigerinatheka semiinvoluta*, *G. kugleri*, *G. barri* Bronnimann, and *Globigerina sellii* (Borsetti).

The Paleogene of the Crimea and North Caucasus is extremely rich in planktonic foraminifera as far as the number of specimens is concerned, but the number of genera and species is reduced. The degree of this impoverishment is not the same throughout the various intervals of geological time.

In the Danian and Early Paleocene, planktonic foraminiferal assemblages differ slightly from the Mediterranean, in that *Globorotalia pusilla* Bolli is absent and *G. trinidadensis* Bolli, and *Acarinina uncinata* (Bolli) are rare or totally absent.

A comparison of the lists of planktonic foraminifera for the Late Paleocene *Globorotalia pseudomenardii* and *Globorotalia velascoensis* Zones of the Mediterranean and the Crimean-Caucasian area shows that they are almost identical. But when comparing the assemblages of planktonic foraminifera, the difference becomes obvious: in the Late Paleocene of the Crimean-Caucasian area, *Globorotalia* species are rare, and paleocoenoses very often consist of representatives of *Acarinina* and *Globigerina*. These paleocoenoses evidently are unusual for micropaleontologists working in the Mediterranean or Caribbean areas who are accustomed to tropical foraminiferal assemblages with abundant representatives of *Globorotalia*.

In the Early Eocene, the difference between the faunas of planktonic foraminifera from the same two areas is insignificant again; it consists of the absence of *Globorotalia palmerae* and *Globigerina senni* and a scarcity of *Acarinina aspensis* in the Crimea and Caucasus.

The most significant differences are found in the Middle to Late Eocene. In the deposits of this age in the Crimea and the North Caucasus there are no representatives of *Clavigerinella*, *Orbulinoides*, *Cribrohantkenina*, *Hantkenina aragonensis* Nuttall, *H. dumblei*, *H. suprasuturalis* Brönnimann, *Globigerinatheka semiinvoluta*, *Globorotalia renzi* Bolli, *G. spinulosa* Cushman, *G. pseudomayeri* Bolli, *G. bolivariana*, *G. lehneri*, *G. cerroazulensis s. l.*, *Globigerina senni*, *G. higginsi*, *G. tripartita*, *Globigerinita howei* Blow and Banner, *G. echinata*, *Globorotaloides suteri* Bolli, and others.

The Oligocene Maikop Formation of the Crimea and North Caucasus is composed of noncalcareous and slightly calcareous clays that are poor in plankton. Therefore, it is difficult to draw conclusions about similarities or differences between planktonic foraminifera of the Oligocene of the Mediterranean and those of the Crimean-Caucasian area.

TEXT-FIGURE 4
Caribbean area showing locations of drill sites and surface sections discussed.

2) Stratigraphic ranges of some genera and species of planktonic foraminifera in the Paleogene of the Crimean-Caucasian area make up only a part (local epibole, Teilzone) of the complete stratigraphic ranges (biozone) of these taxa in the Mediterranean Paleogene.

For example, in the Mediterranean, the genus *Hantkenina* is developed from the base of the Middle Eocene to the top of the Upper Eocene. Representatives of this genus [*H. liebusi* (Shokhina), *H. lehneri*] in the Crimea and North Caucasus appear later (the *Acarinina rotundimarginata* Zone) and disappear earlier (*H. longispina* at the top of the *Globigerina turcmenica* Zone). In the Mediterranean and Armenia, the genus *Globigerinatheka* appears in the *Globigerinatheka kugleri* Zone and continues almost to the top of the Eocene. In the Crimea and the North Caucasus, the first very rare specimens of *Globigerinatheka* (*G. index*) were recorded in the *Acarinina rotundimarginata* Zone; they become numerous only from the *Hantkenina alabamensis* Zone and disappear in the middle part of the Late Eocene.

Species of *Globorotalia spinulosa* and *G. renzi* characterize the entire Middle Eocene in the Mediterranean. They disappear at the top of the *Hantkenina alabamensis* Zone in Armenia and are absent in the North Caucasus.

In the Mediterranean and Armenia, *Globorotalia cerroazulensis s.l.* appears in great numbers in the *Orbulinoides beckmanni* Zone and disappears at the top of the Late Eocene. It is representative of the Late Eocene only in the Crimea and North Caucasus.

Orbulinoides beckmanni ranges in the Mediterranean throughout the zone of this name. In Armenia, only rare specimens of this species occur in the basal layers of the synchronous *Hantkenina alabamensis* Zone, and there are no specimens of *O. beckmanni* present in the North Caucasus.

In the Mediterranean and South Armenia, *Globigerinatheka index* has a wide stratigraphic range, from the *Globigerinatheka kugleri* Zone to the top of the Eocene. In the Crimea and North Caucasus, its range is discontinuous—rare in the *Acarinina rotundimarginata* Zone, abundant in the *Hantkenina alabamensis* Zone; there is no *Globigerinatheka index* in the *Globigerina turcmenica* Zone. The second appearance of the species has been recorded in the early and middle part of the Late Eocene.

Certainly, the geographical distribution of planktonic foraminiferal species is determined by a complex combination of the influence of local facies conditions and climatic zonation. It is difficult to differentiate between the influences of these factors. It is probable that the study of the influence of climatic zonation on the distribution of planktonic foraminifera is easier in Cenozoic sediments from oceanic basins, where local conditions were more stable.

NEOGENE (H.M.B.)

After the Late Cretaceous and Paleogene planktonic foraminiferal taxa and the zonal subdivisions based on them had been established on a world-wide basis (up to approximately 50–55°N. and S.), it was expected that the Neogene forms could be put to use stratigraphically in a similar way once the faunas were sufficiently well known. It became apparent, however, that the end of the Eocene, or the onset of the Oligocene, where a considerable change in the planktonic foraminiferal fauna took place, marked the beginning of a period in which planktonic foraminiferal species, in particular index forms such as the subspecies of *Globorotalia fohsi* Cushman and Ellisor, or *Globigerinatella insueta* Cushman and Stainforth, became progressively more restricted geographically as a result of latitudinal climatic belts becoming more pronounced. This phenomenon was realized some time ago and discussed on various occasions (*e.g.*, Bolli, 1964). As a result, additional zonal schemes were proposed to supplement those originally based on tropical faunas, such as in the Mediterranean and Australia-New Zealand regions.

Over the past few years little refinement has been added to the Miocene zonal schemes. The situation is different for the Pliocene to Holocene where, based on planktonic foraminifera, zonal resolution could be about doubled (Bolli and Premoli Silva, 1973) compared with schemes established only a few years ago, such as the

N zones of Blow (1969) or those proposed by Bolli and Bermudez (1965) and Bolli (1970) (see text-figure 6). This much higher resolution could be obtained for the tropical (Caribbean, Timor Trough) and temperate (Mediterranean) Pliocene, and for the Pleistocene/Holocene in certain tropical provinces such as the Caribbean and the Timor Trough area.

It is shown below that in the Caribbean a number of Pliocene-Pleistocene index forms possess anomalous distribution patterns. These differ markedly from those known from the Indo-Pacific at comparable latitudes.

The closing of the Isthmus of Panama that blocked the flow of water masses between the Atlantic and Pacific may have had an influence on this, and may have been the cause of subsequent, partially divergent, faunal developments in the two oceans. The general Pliocene distribution pattern of some species in the Caribbean area also indicates temporary provincial predominance of certain taxa that include *Globorotalia multicamerata* Cushman and Jarvis, *G. miocenica* Palmer, *G. exilis* Blow, and *G. pertenuis* Beard. This resulted in a temporary replacement of *G. menardii* (d'Orbigny) *s.l.*, *G. tumida* Brady *s.l.*, and *Pulleniatina s.l.* These anomalous Caribbean faunal distributions are discussed below, and compared with the distribution patterns found in Java and the Timor Trough. The results are shown in text-figure 7.

The sections on which the observations are based are:

Caribbean (text-figure 4). DSDP Sites of Legs 4 and 15 (Bolli, 1970; Bolli and Premoli Silva, 1973); well Cubagua-1 on Cubagua Island, Venezuela (Bermudez and Bolli, 1969); surface sections in Jamaica (Bolli, 1970).

Indo-Pacific (text-figure 5): Well Bodjonegoro-1, Java (Bolli, 1966*a*); DSDP Site 262, Timor Trough (Rögl, 1974).

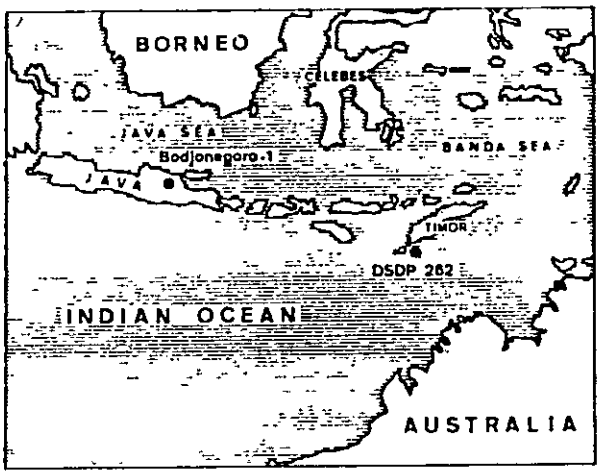
It is the purpose of this presentation to point out a number of anomalies in stratigraphic and paleogeographic species distributions that at least partially affect and limit the application of established zonal schemes.

The species discussed (text-figure 7) include:

a) *Globigerina nepenthes* Todd as an example of a rather erratically occurring, and therefore unreliable, index form.

b) *Globoquadrina altispira* (Cushman and Jarvis), a species whose extinction level appears to be constant over wide areas.

c) *Globorotalia menardii s.l.*, *G. plesiotumida* Banner and Blow-*G. tumida*, and *Pulleniatina*, which show continuity in occurrence and evolution in the Indo-Pacific but interruption during most of the Pliocene in the Caribbean area.



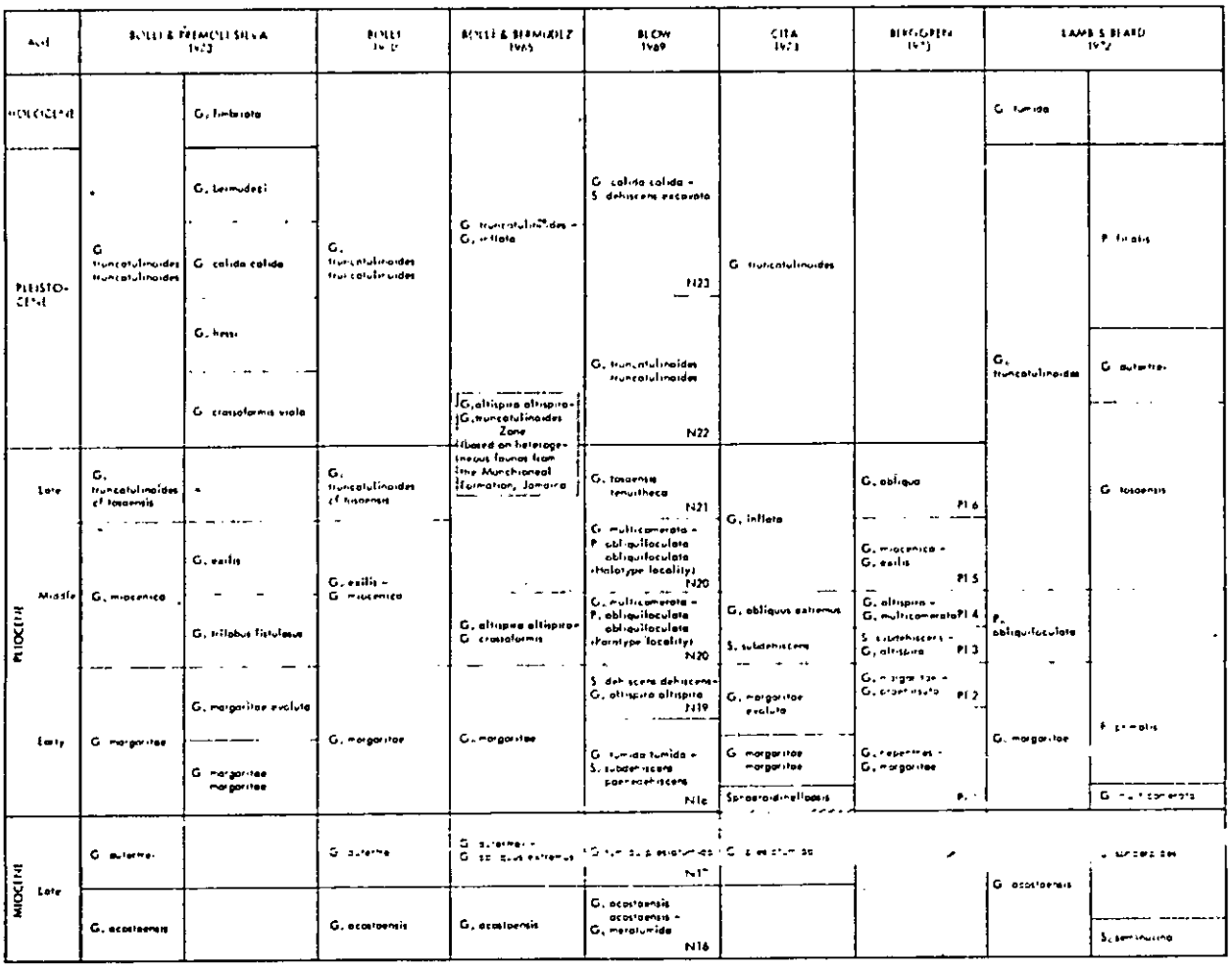
TEXT-FIGURE 5
Location of well Bodjonegoro-1 and DSDP Site 262 in Indonesia.

d) *Globorotalia pseudomiocenica* Bolli and Bermudez-*G. miocenica*, *G. multicamerata*, and *G. pertenuis*-*G. exilis*. These taxa are restricted in their typical development to the tropical Atlantic province, including the Gulf of Mexico and the Caribbean. During most of the Caribbean Pliocene they replace *Globorotalia menardii s.l.*, *G. plesiotumida*-*G. tumida*, and *Pulleniatina* populations, which are virtually absent there during this period.

Another factor, in addition to irregular species distribution, that influences correlations of sections and their subdivision into zones, is the often considerable variability in thickness of a given sediment interval. Faunal charts based on condensed sequences from deep-sea piston cores, which frequently are also discontinuous, may give quite different distribution patterns than those of more extended and probably more continuous sections. Some examples for this were quoted by Bolli (1970); stratigraphic sections from shelf areas (*e.g.*, well Bodjonegoro-1 of Java) may be 100 or more times as thick as equivalent intervals from certain deep-sea sections. One obviously has to be cautious in drawing conclusions on faunal distributions for establishing zonal schemes from strongly condensed and discontinuous sections alone.

Irregularities in faunal distribution patterns, even within the same climatic belt, and variation in continuity and thickness of sections on which ranges are based, belong, therefore, to the main causes for discrepancies in zonal schemes and their correlation.

Finally, after discussion of the above taxa, some comments are made on the applicability, particularly in the Caribbean area, of the zonal schemes proposed by Blow (1969) and Berggren (1973).



TEXT-FIGURE 6
Tropical Pliocene-Pleistocene planktonic foraminiferal zonation schemes.

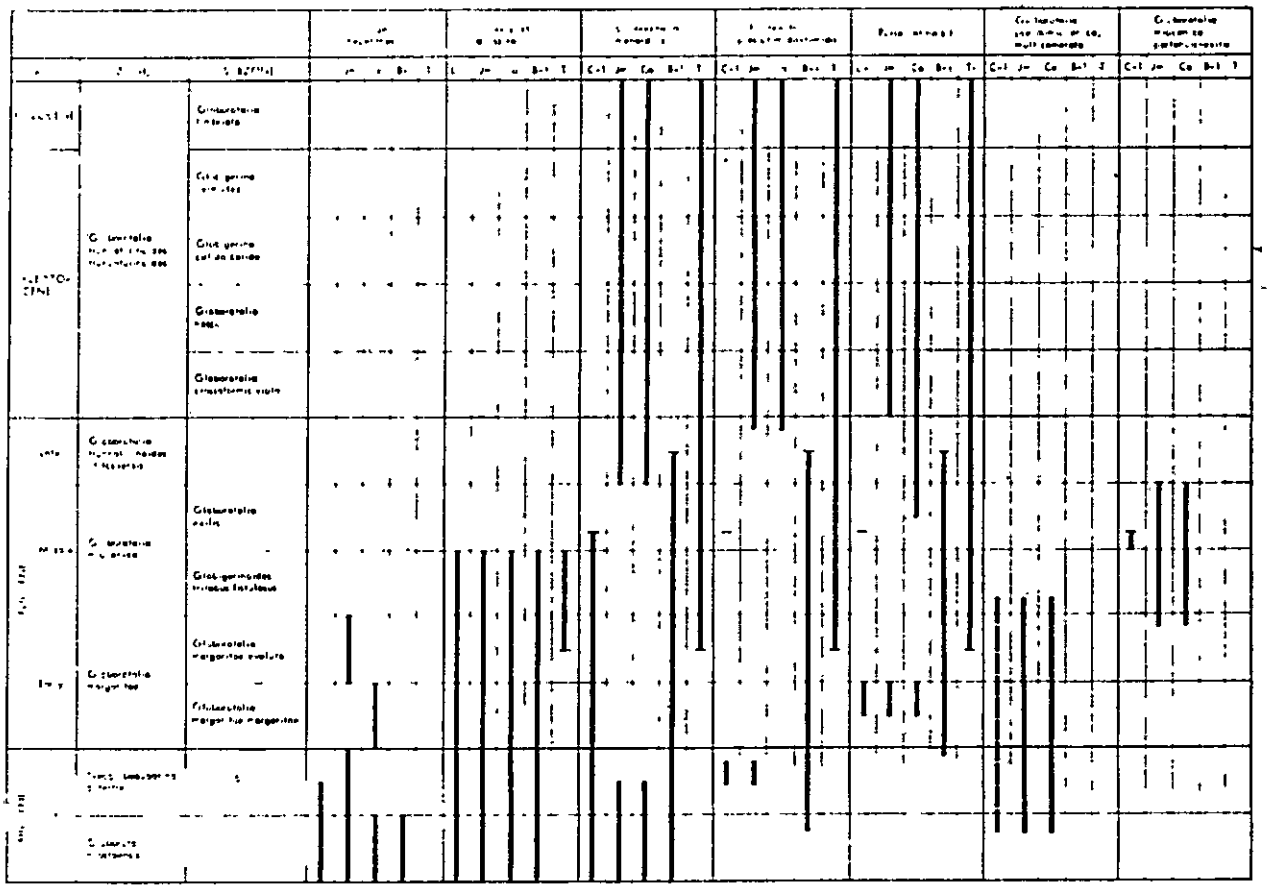
All Neogene zonation schemes proposed thus far, particularly those for its upper part, are applicable only to more or less limited provinces, such as tropical areas in general, the Caribbean, the Mediterranean, and the Australia-New Zealand province. It is suggested, therefore, that in addition to an exact documentation of each type section on which a newly proposed zonal interval is based, authors should also, as far as possible, indicate the approximate area within which the unit can be reliably recognized.

Globigerina nepenthes Todd

This species has been proposed as a zonal marker by a number of authors, including Blow (1969), Berggren (1973), Cita and Premoli Silva (1968), and Cati *et al.* (1968).

Although typical *Globigerina nepenthes* are readily recognized, specimens have on numerous occasions been identified as *nepenthes* that, in fact, can be assigned only doubtfully to this species. This is the case in particular with specimens from near the higher latitudinal limits of the species range, *e.g.*, the Mediterranean or the Paratethys. Another factor that limits the use of *G. nepenthes* even more is its erratic occurrence not only in temperate but also in tropical areas. In the Caribbean, for example, the species may occasionally be seen in floods; in normal, open marine samples it is usually present, though often rare, but only slight ecologic changes may be sufficient to cause its complete absence.

As shown in text-figure 7, the highest stratigraphic occurrence of *G. nepenthes* in the Caribbean is in the



TEXT-FIGURE 7
Ranges of selected planktonic foraminiferal species in the Late Miocene to Holocene of the Caribbean and Indo-Pacific.
Horizontal line at bottom or top of range indicates that distribution is here limited because section is drilled or cores are available.
C-1 Well Cubagua-1, Cubagua Island, Caribbean, Jm Jamaica; Ca Caribbean DSDP Sites of Legs 4 and 15, B-1 : Well Bodjonegoro-1 ; Ti Timor Trough DSDP Site 262 of Leg 27.

Globorotalia margaritae evoluta Zone in Jamaica. In well Cubagua-1, the species, apparently for ecologic reasons, disappears within the *Globorotalia dutertrei* Zone. In the Caribbean DSDP sections, the species is rare and occurs only erratically in Site 31 as high as the *Globorotalia margaritae margaritae* Zone. In the Java well Bodjonegoro-1, rich in planktonic foraminifera throughout, *Globigerina nepenthes* is represented in the numerous and closely sampled intervals by only a few specimens, all restricted to the *Globorotalia acostaensis* Zone.

The different interpretations of the species concept and the irregular pattern on occurrence and distribution suggest that *Globigerina nepenthes* should be used as a biostratigraphic index form with great caution. In particular its top occurrence should be used, as demonstrated in text-figure 7, only in combination with other taxa.

Globoquadrina altispira (Cushman and Jarvis)

Globoquadrina altispira shows a much more regular distribution pattern in the Upper Miocene and Pliocene than *Globigerina nepenthes*. Although as a rule it is not very frequent, the species is fairly persistent. Its extinction level in the Middle Pliocene at about the boundary of the *Globigerinoides trilobus fistulosus* Subzone and the *Globorotalia exilis* Subzone coincides well in all sections shown in text-figure 7. The extinction level can therefore be regarded as a fairly reliable datum, at least in tropical and subtropical areas.

The ***Globorotalia menardii*** group and related taxa (*G. plesiotumida, G. tumida, G. pseudomiocenica, G. multicamerata, G. pertenuis, G. exilis*).

Morphologic forms included in the *Globorotalia menardii* group comprise a considerable variability, and range in age from Middle Miocene to Recent. Attempts have been made to subdivide this complex. The *menardii* group apparently has its origin in the Early Miocene, beginning with *G. archeomenardii* Bolli and evolving via *G. praemenardii* (Cushman and Stainforth) into Middle Miocene *G. menardii* forms, such as described from the Lengua Formation of Trinidad.

Beginning with the Late Miocene, and during the Pliocene, a number of morphologically distinct forms evolved, presumably from the *G. menardii* stock, some of them largely confined to the tropical Atlantic-Gulf of Mexico-Caribbean. Some proved to be fairly short-lived and also paleogeographically restricted, while others continued as separate lineages until the present day.

Considerable morphological variability also exists in *G. menardii s.l.* living today, where two forms are distinguished, a more robust *G. menardii menardii* (d'Orbigny) and a more delicate *G. menardii cultrata* (d'Orbigny) (see Bolli, 1970, pl. 5).

The principal taxa that can be regarded as having branched off directly or indirectly from the *G. menardii* stock are:

1. *G. plesiotumida-G. tumida* (including *G. tumida fexuosa* Koch)
   Range: Late Miocene-Recent.
2. *G. pseudomiocenica-G. miocenica*
   Range: Late Miocene-Middle Pliocene.
3. *G. multicamerata*
   Range: Early Pliocene-lower Middle Pliocene.
4. *G. pertenuis-G. exilis*
   Range: upper Lower Pliocene-Middle Pliocene.

Of these, the *G. plesiotumida-G. tumida* lineage is found world-wide under tropical-subtropical conditions. The other three were also restricted largely to the tropical-subtropical belt, but within it their paleogeographic distribution was largely confined to the Caribbean, the Gulf of Mexico, and the Atlantic. These taxa have not been found in typical development in the Indo-Pacific, although morphologically similar forms were described from these areas.

Observations in various sections of the Caribbean show that with the development and during the range of *G. pseudomiocenica, G. miocenica, G. multicamerata,* and *G. pertenuis-G. exilis,* the taxa *G. menardii s.l., G. tumida s.l.,* and *Pulleniatina* become entirely or to a large degree replaced by the former group. This is the case in all examined DSDP and Jamaica sections, but not in the Cubagua-1 well section on the island of Cubagua. There, *G. menardii* continues more or less typically also through the interval where it is replaced in the other Caribbean sections. *Globorotalia pseudomiocenica* is weakly represented in the early part of Cubagua-1, *G. miocenica* with a few specimens only immediately above the top of the *Globorotalia margaritae* Zone. *Globorotalia multicamerata* and *G. pertenuis-G. exilis* do not occur at all in Cubagua-1. The very limited occurrence of representatives of the *G. plesiotumida-G. tumida* lineage and *Pulleniatina* falls in line, on the other hand, with that in the DSDP and Jamaica sections. Ecologic conditions in the area of Cubagua must have been somewhat different from those of most of the Caribbean and must be responsible for this difference in faunal composition.

Whether a distribution pattern similar to that found in most of the Caribbean area, that is, the virtual exclusion of *G. menardii, G. tumida,* and *Pulleniatina* during the presence of *G. multicamerata, G. pseudomiocenica-G. miocenica* and *G. pertenuis-G. exilis,* also persisted in the whole or part of the Gulf of Mexico area and the tropical-subtropical Atlantic province still remains to be investigated.

The planktonic foraminiferal distribution pattern that exists in the Caribbean has its distinct influence on the zonal schemes applied there. In the Pliocene, *G. pseudomiocenica-G. miocenica, G. multicamerata,* and *G. pertenuis-G. exilis* make excellent index forms and in part at least also in the Gulf of Mexico and tropical Atlantic (text-figure 7).

For records on the occurrence of *G. multicamerata, G. miocenica,* and *G. pertenuis-G. exilis* in the Gulf of Mexico, see Lamb and Beard (1972), who figured these species and cited their occurrence from several sections.

The most northerly records of *G. multicamerata, G. exilis,* and *G. miocenica* from Northern Atlantic DSDP sections are from Leg 14, Site 139 (lat. 23°31.14'N., long. 18°42.26' W.), the most southerly from Leg 3, Site 16 (lat. 30°20.15'S., long. 14°42.79'W.). Between these extremes of north and south latitudes the species were found in a number of additional sites of DSDP Legs 3, 4, and 14.

Genus ***Pulleniatina*** Cushman

The genus *Pulleniatina* in the Caribbean area has a distribution pattern similar to that of *Globorotalia menardii s.l.* and *G. plesiotumida-G. tumida.* It makes a first but short-lived initial appearance with *P. obliquiloculata primalis* Banner and Blow, restricted in Jamaica, the DSDP sections and Cubagua-1 to the

upper part of the *Globorotalia margaritae margaritae* Subzone. The genus is absent throughout the *Globorotalia margaritae evoluta* and *Globigerinoides trilobulinoides fistulosus* subzones, to reappear again in some DSDP sections within the *Globorotalia exilis* Subzone, and to continue from there without further noticeable interruption to the Recent. In the sequence of the Jamaica type locality samples selected by Blow (1969) for his zonal scheme, *Pulleniatina* only reappears again in the Pleistocene after its short initial appearance in the upper part of the *Globorotalia margaritae margaritae* Subzone.

The interval of absence of *Pulleniatina* in the Caribbean is comparable to that of the *G. menardii s.l.* and *G. plesiotumida-G. tumida* lineages, though somewhat shorter.

By comparison, in the Java-Timor Trough region (Bodjonegoro-1, DSDP Site 262), *Pulleniatina* first appears immediately below the *Globorotalia margaritae margaritae* Subzone and continues without interruption to the Recent, as do *G. menardii s.l.* and *G. plesiotumida-G. tumida*.

COMMENTS ON ZONES N 17-21 OF BLOW (1969), ESTABLISHED IN JAMAICA, AND THEIR APPLICATION IN THE CARIBBEAN AREA

Globorotalia tumida plesiotumida Zone (N 17): The base of this zone is defined by the first evolutionary appearance of *G. tumida plesiotumida* from *G. merotumida* Blow and Banner. This evolutionary lineage cannot be applied to Caribbean zonation because in all sections examined, the evolutionary sequence is nonexistent or at best present only erratically and incompletely. It has, for instance, not been seen in any of the Caribbean DSDP sites of Legs 4 and 15. The initial stage of the lineage is present for only a very short interval in Cubagua-1, in some surface sections on the Araya peninsula, and very sporadically in Jamaica. In the Java well Bodjonegoro-1, where the evolutionary lineage *G. plesiotumida-G. tumida* appears to be continuous and uninterrupted, the zonal definition may be applied.

Globorotalia tumida-Sphaeroidinellopsis subdehiscens paenedehiscens Zone (N 18): The base of this zone is defined by the first evolutionary appearance of *G. tumida tumida*. In the Caribbean sections, this zone is in most sections impossible to recognize for the same reasons as outlined above under N 17.

Sphaeroidinella dehiscens-Globoquadrina altispira altispira Zone (N 19): The base of this zone is defined by the first appearance of *S. dehiscens dehiscens* (Parker and Jones). This is applicable in the investigated Caribbean sections. Examination of the type samples used by Blow indicate that the "holotype" sample for N 19 (ER 146/44, Buff Bay Formation, Jamaica) contains *Globorotalia multicamerata, G pseudomiocenica, G. miocenica, G. pertenuis,* and *G. margaritae evoluta* Cita and thus falls into the upper part of the *Globorotalia margaritae evoluta* Subzone of Bolli and Premoli Silva (1973).

Globorotalia multicamerata-Pulleniatina obliquiloculata obliquiloculata Zone (N 20): The base of this zone is defined by the first evolutionary appearance of *G. acostaensis pseudopima* Blow. Caribbean DSDP sections show that this four-chambered subspecies has a longer range than indicated by Blow. In Sites 29–31 it first appears at about the base of the *Globorotalia margaritae* Zone (approximately the base of Blow's N 18), and continues from there into the Pleistocene. Berggren (1973) regarded N 20 as time-equivalent to the upper part of N 19.

The "holotype" sample for Blow's Zone N 20 (ER 156, Bowden Formation) contains *Globorotalia exilis* and *G. miocenica*, but is without *Globoquadrina altispira, Globigerinoides trilobus fistulosus* (Schubert) or *G. obliquus extremus* Bolli, and thus clearly falls into the *Globorotalia exilis* Subzone of Bolli and Premoli Silva, and the *Globorotalia miocenica-G. exilis* Zone (Berggren, 1973, pl. 5), and not, as Berggren indicated, into his *Sphaeroidinellopsis subdehiscens-Globoquadrina altispira* Zone (*ibid.*, pl. 3).

Blow's "paratype" sample for N 20, ER 193, Bowden Formation, on the other hand, contains, in addition to *Globorotalia miocenica* and *G. exilis, G. pertenuis, Globigerinoides trilobus fistulosus, G. obliquus extremus,* and *Globoquadrina altispira*. In the Bolli and Premoli Silva zonal scheme, this sample falls into the *Globigerinoides trilobus fistulosus* Subzone, or, in Berggren's (1973) terms, into his *Sphaeroidinellopsis subdehiscens-Globoquadrina altispira* Zone (*ibid.*, pl. 3). These relationships are shown in text-figure 6.

Blow characterized Zone N 20 by the co-occurrence of *Pulleniatina obliquiloculata obliquiloculata, P. obliquiloculata praecursor* Banner and Blow, and *Globorotalia multicamerata*, and in the Atlantic/Caribbean province only, by *Globorotalia miocenica*. This is not in agreement with the examined "holotype" sample of N 20 (ER 156), where no *Globorotalia multicamerata* or representatives of *Pulleniatina* could be seen. *Globorotalia multicamerata* is absent in this sample for stratigraphic reasons (already extinct), *Pulleniatina* for ecologic reasons.

Globorotalia tosaensis tenuitheca Zone (N 21): The base of this zone is defined by the first evolutionary appearance of *G. tosaensis tenuitheca* Blow. The top is immediately below the first evolutionary appearance of *G. truncatulinoides truncatulinoides.*

Because of the indistinct evolutionary sequence from *G. tosaensis* to *G. truncatulinoides*, such an interval is very difficult to recognize in the Caribbean sections.

COMMENTS ON ZONES PL 1-PL 6 OF BERGGREN (1973)

Globigerina nepenthes-Globorotalia margaritae Zone (Pl 1): In the text of Berggren (1973, p. 6) this zone is also named the *Globigerina nepenthes-Globorotalia tumida* Zone. The base is defined (as that of Blow's N 18) by the first evolutionary appearance of *Globorotalia tumida tumida* from *G. tumida plesiotumida*. As pointed out in the comments on the N zones, this definition may be used with limited accuracy in areas where the evolutionary sequence is clearly recognizable, as for example in well Bodjonegoro-1 of Java, but is not applicable in the Caribbean area where the lineage is not at all or only incompletely developed.

Globorotalia margaritae-Globorotalia praehirsuta Zone (Pl 2): The base of this zone is defined by the extinction of *Globigerina nepenthes*. As discussed under *Globigerina nepenthes*, and shown in text-figure 6, this species is very erratic in its occurrence and distribution. Neither its top nor its base can therefore be considered suitable for delineating a zonal boundary. This is not only true for the Caribbean and Indo-Pacific, but apparently applies world-wide.

Sphaeroidinellopsis subdehiscens-Globoquadrina altispira Zone (Pl 3): The base of this zone is defined by the extinction of *Globorotalia margaritae s.l.* From observations in the Atlantic (including the Mediterranean, Gulf of Mexico, and Caribbean) and the Indo-Pacific, this datum can be applied world-wide.

Globoquadrina altispira-Globorotalia multicamerata Zone (Pl 4): The base of this zone is defined by the extinction of *Sphaeroidinellopsis seminulina subdehiscens* (Blow). This datum can be recognized, but is often not distinct because juvenile specimens of *Sphaeroidinella* may be without additional apertures and consequently be taken as belonging to *Sphaeroidinellopsis*. This tends to extend the range of the latter genus upward. Furthermore, the two genera occur somewhat erratically in some areas.

Globorotalia miocenica-Globorotalia exilis Zone (Pl 5): The base of this zone is defined by the extinction of *Globoquadrina altispira* and *Globorotalia multicamerata*. These appear to be reliable data, world-wide for *G. altispira*, restricted to the tropical Atlantic/Gulf of Mexico/Caribbean province for *G. multicamerata*. This zone corresponds to the *Globorotalia exilis* Subzone of Bolli and Premoli Silva (1973).

Globigerinoides obliqua Zone (Pl 6): The base of this zone is defined by the extinction of *Globorotalia miocenica*, the top by the extinction of *Globigerinoides obliqua* and the first appearance of *Globorotalia truncatulinoides truncatulinoides*. The interval of this zone correlates with the *Globorotalia truncatulinoides* cf. *tosaensis* Zone of Bolli (1970). Berggren's species interpretation of *Globigerinoides obliqua* apparently differs from that of Bolli, the author of *G. obliquus obliquus* and *G. obliquus extremus*. In the Caribbean sections examined, *G. obliquus obliquus* does not go higher than approximately the top of the *Globorotalia margaritae margaritae* Subzone, while *Globigerinoides obliquus extremus* ranges from the base of the *Globorotalia dutertrei* Zone to approximately the base of the *G. exilis* Subzone or slightly into it. Berggren's *Globigerinoides obliqua* should be re-examined in the light of this evidence, in particular to determine whether his specimens are in fact not *Globigerinoides ruber* (d'Orbigny) with oblique end chambers.

The base of Berggren's zone Pl 6, defined on the extinction of *Globorotalia miocenica*, will be difficult to recognize outside the area of its typical occurrence that is outside the tropical Atlantic Gulf of Mexico and Caribbean provinces. The top of the zone, marked by the first occurrence of *Globorotalia truncatulinoides truncatulinoides* is of world-wide significance.

CONCLUSIONS

Because the composition of planktonic foraminiferal faunas is determined by climate and locally restricted environmental conditions, numerous zonal schemes have been proposed. They have satisfied the requirements of regional and provincial stratigraphy well. Yet, stratigraphy still faces problems of global correlation of Cenozoic deposits, on continents and in oceans. It is the study of these problems that are now underway or are being planned by UNESCO and JOIDES. Important contributions toward solving them are expected to come from micropaleontologists and stratigraphers. to arrive at reliable biostratigraphic subdivisions and correlations, they have to carefully consider the influence of climatic belts and local environments on the composition of planktonic foraminiferal associations.

The following possibilities of establishing and applying zonal schemes may be considered:

1) Different zonal schemes reflecting local anomalies in planktonic foraminiferal associations might be adopted for different regions. Correlation of these schemes would be carried through to regions with sediments containing intermediate (transitional) types of microfaunas. There will not only be three such schemes as suggested by Jenkins (1973), but many more. Correlation between numerous schemes at present in existence is often difficult on a global scale.

2) The detailed zonal scheme of the Cenozoic of the Caribbean area (text-figure 1) might be adopted as a universal model for tropical, subtropical, and temperate areas (approximately between latitudes 50–55°N. and 45–50°S.). Not all zones of the tropical area can be distinguished in subtropical and temperate areas. In such cases, a combination of two or more adjacent zones (*e.g.*, from the *Globorotalia kugleri* to *Globigerinita dissimilis* Zones) should be used in preference to a newly established zone.

3) The zonal scheme of the Paleogene and Neogene of the Caribbean area might be regarded as a base. By combining it with other schemes one can attempt to establish a universal scheme for the Cenozoic tropical, subtropical, and temperate areas. This requires that only such zones as have world-wide application maintain their rank. Zones of only local significance should be confined into larger subdivisions of world-wide distribution. Zones applicable only more locally are then named "subzones." A universal scheme would thus consist of zones of global extension and of subzones of local significance only. Within a zone (in horizontal direction), the microfaunal changes depend on climatic belts and local environmental conditions. Therefore, each zone would be characterized by several paleocoenoses of planktonic foraminifera.

Of the three proposed possibilities of applying zonal schemes, that of the universal scale (3) is favored by the authors as a satisfactory basis for global and local Cenozoic stratigraphic subdivision and correlation.

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