

THE UNIVERSITY OF KANSAS
PALEONTOLOGICAL CONTRIBUTIONS

July 10, 1981

Paper 104

AN EVALUATION OF PLANKTONIC FORAMINIFERAL
ZONATION OF THE OLIGOCENE

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ABSTRACT

Planktonic foraminiferal content was recorded in detail through Oligocene deep-water sediments in five coreholes (one continuously cored) and two surface sections in Gulf Coast-Atlantic slope region. The sequence of planktonic taxa matches worldwide zonal schemes of several authors and provides a basis for dividing the Oligocene into five zones. Datum levels in upward sequence are extinction of Eocene hantkeninids and globorotaliids, extinction of *Pseudohastigerina micra*, advent of *Globigerina angulisurealis*, extinction of *Globorotalia opima opima*, and advent of *Globorotalia kugleri* s.s. A marked abnormality is the occurrence of the *Globigerinoides* Datum a whole zone lower than its generally accepted position within the *Globorotalia kugleri* Range-zone coincident with the Oligocene-Miocene boundary. This and lesser peculiarities are tentatively attributed to paleoclimatic effects. As guide to the Oligocene-Miocene boundary, the level of joint advent of *Globoquadrina altispira* aff. *altispira* and *Globorotalia fohsi peripheroronda* is suggested.

INTRODUCTION

The main objective of this study was to determine the most reliable taxa for defining a sequence of planktonic foraminiferal zones spanning the Oligocene. As noted previously (Stainforth & others, 1975, p. 74), the base of the Oligocene is generally marked by abrupt

extinction of many planktonic foraminifers, and these were not replaced immediately. Thus, the Oligocene began with assemblages of planktonic foraminifera commonly having a nondescript aspect because neither Eocene indices nor equally distinctive Miocene markers occur. Moreover, the early Oligocene interval, characterized mostly by a relatively

¹Manuscript received November 3, 1980.

cool climate and lowered sea level, is rather inadequately represented in most surface sections. Consequently, zonation of the Oligocene has seemed notably less detailed and less precise than that of other Tertiary intervals.

A secondary objective has been to obtain a detailed biostratigraphic framework that will facilitate integration of zonal schemes based on other microfossil groups (e.g., dinoflagellates, calcareous nannofossils) whose occurrence and differentiation in the same sections are presently being studied. Geographic scope of the study was purposely restricted, therefore, to avoid anomalies related to latitudinal and paleoclimatic differences.

Five submarine coreholes and two well-known surface sections were selected as the basis of the study. The analysis consisted primarily of detailed but routine listing of all planktonic foraminiferal taxa observed in washed residues. "Type" and supplementary slides of all forms were prepared and referred to repeatedly during the study, partly to ensure uniform identification and partly to assist in identifying evolutionary changes. The relative abundance of species was also recorded. For each section a detailed distribution chart was plotted, on which potential zonal datum-levels were discernible as clear-cut extinctions and/or first appearances of distinctive taxa. Later, data from these individual charts were integrated into a plot of zones and subzones recognizable throughout the study area. A few apparent anomalies between local records and the regional zonal pattern were then investigated by reexamination of the samples in question, some anomalies being verified and others disproved.

The text and illustrations of this paper were ready for publication late in 1977 but did not go to press until three years later. In the meantime, numerous papers on definition, correlation and zonation of the Oligocene had appeared, engendered to an appreciable extent by international groups such as IGCP Projects 25, 114, and 174; the Regional Committee on Mediterranean Neogene Stratigraphy; and the IUGS Working Group on the Paleogene-Neogene Boundary. One of us (RMS) attended recent meetings of these groups in Bratislava (1975), Tokyo (1976), California (1977, 1978), Italy (1978), and Athens (1979).

Consequently we are sufficiently aware of the status of Oligocene studies to feel that our data still deserve presentation as a significant example of microfaunal changes in the interval from Late Eocene to Early Miocene.

The following references are representative of recent contributions to the theme and deserve study, even though they are not specifically mentioned in the following text: Alvinerie and others (1977); Anonymous (1977, 1978); Berggren (1978); Berggren and Aubert (1976); Bizon and Müller (1979a, b); Borsetti and others (1979); Drooger and others (1976); González Donoso and Molina (1978); Hardenbol and Berggren (1978); Meulenkamp (1975); Poignant and Pujol (1976, 1979); Poore and Brabb (1977).

Repository.—Specimens used in obtaining the original SEM photographs here reproduced are filed at Exxon Production Research Company, Houston. Unfigured materials, including "type" and supplementary slides for the identified taxa and picked slides for each of the core and surface samples, are also on file.

Acknowledgments.—We are indebted especially to J. F. van Sant, Jan Hardenbol, and L. E. Stover of Exxon Production Research Company for guidance in carrying on these investigations, and to others of the same organization, especially J. H. Beard, who initially investigated the foraminifera and other microfossils in the coreholes. Dr. Isabella Premoli Silva of Milan, Italy, and Woods Hole and Hermann Duque Caro of Bogotá, Colombia, supplied important information on occurrences of the *Globigerinoides* Datum. Most of the scanning electron microscope (SEM) photographs were made by Hardie Turnbull, Imperial Oil Ltd. in Calgary; a few were prepared by R. D. Hockett of Exxon Production Research Company in Houston. Acknowledgment is made to R. M. Jeffords, Exxon Production Research Company, for editing the manuscript and for adjusting the format for publication.

Special appreciation is expressed to Exxon Company, U.S.A. for making available for this analysis the cores from the Atlantic slope and the northern Gulf of Mexico. The work was supported by Exxon Production Research Company, whose management gave permis-

sion to publish this report and approval to include it in the Harold Norman Fisk Memorial

Papers sponsored by Exxon Company, U.S.A.

MATERIAL STUDIED

The backbone of this study is a set of continuous or evenly spaced cores from several submarine coreholes in the northern Gulf of Mexico and Atlantic slope (Fig. 1). Being mostly from deep, offshore facies, these cores yield phenomenally rich assemblages within which chronologically significant changes are reasonably closely spaced because of the slow rates of deposition in deep water. In a few, identification of species was difficult to im-

possible because of poor preservation resulting from preburial carbonate solution or postburial glauconitization. Presence of such indeterminate material explains apparent gaps in some species ranges plotted on accompanying charts (Figs. 2-5).

Specifically, use was made of the following coreholes; depths indicate feet below sea level.



FIG. 1. Distribution of Atlantic slope and northern Gulf of Mexico coreholes and Alabama surface sections; solid circles indicate study localities, solid squares major cities.

Northern Gulf of Mexico

Corehole 16-4/4A (25° 58.4' N., 95° 43' W.); 2,246 to 2,524 feet. Intermittent coring of mid-Oligocene to mid-Eocene.

Corehole 29-42 (28° 45.9' N., 87° 20.7' W.); 4,681 to 5,060 feet. Intermittent coring from top of the Oligocene to top of the Eocene (Fig. 2).

Corehole 32-45 (27° 07.8' N., 85° 13.9' W.); 5,391 to 5,777 feet. Intermittent coring from lower half of the Oligocene to top of the Eocene (Fig. 3).

Corehole 30-43 (28° 01.1' N., 86° 24.7' W.) and Corehole 35-46 (28° 131.1' N., 86° 49.1' W.) were examined briefly, but the Oligocene is missing in both at an unconformity.

Atlantic Slope

Corehole 5/5B (33° 08' N., 77° 15' W.); 951 to 1,673 feet. Continuous coring of entire Oligocene; the key section (Fig. 4).

Corehole 15 (38° 46' N., 72° 48' W.); 5,081

to 5,204 feet. Intermittent coring of basal Oligocene and Eocene; sparse, poorly preserved planktonic assemblages.

Other

A few corecatcher samples from JOIDES Corehole 3-14 (Charm, Nesteroff, & Valdes, 1969) were examined; these appear to match other sequences studied, but the data are not incorporated here because the locality is far distant in the west-central Atlantic.

Data from Gulf Coast surface sections in Alabama [2 separate samplings each from the Little Stave Creek section (Bandy, 1949), NW of Jackson, Clarke Co., and St. Stephens quarry, old St. Stephens, Sec. 14, T. 7N., R. 1W., Washington Co.], intended to supplement the corehole data, were disappointing. Although the Oligocene interval is physically thick and contains some richly foraminiferal beds, the identifiable planktonic assemblages represent only the lowermost zone.

ZONATION IN STUDY AREA

FAUNAL SEQUENCE AND ZONAL CRITERIA

Distribution charts of the recorded planktonic species were prepared for all the sections studied; those for Coreholes 5/5B, 29-42, and 32-45 are included here (Figs. 2, 3, 4A,B,C), and the others are summarized in the text. Species are thereby shown to occur in essentially the same sequences and patterns at all localities. Furthermore, ranges of species having limited extent agree closely on the whole with patterns already postulated in accepted zonal schemes. Specific deviations from the general pattern are noted in the following discussion. Some of the data presented here were summarized by Lamb and Stainforth (1976), who referred to Coreholes 5/5B and 32-45 as A and B, respectively.

Desirable features of zonal markers are morphologic distinctness, well-defined lower and/or upper limits of range, and consistent presence between these limits. Based on these criteria, 21 taxa ranging from genus to sub-

species are given key importance in biostratigraphic subdivision of the Upper Eocene to lowest Miocene interval (Fig. 5). A comparable number of additional taxa are plotted on distribution charts for the coreholes as being representative of all or part of the interval, but for various reasons they are unsuited for use as zonal markers. The section on nomenclature and stratigraphic distribution of taxa mentions yet other taxa that were recorded in the faunal analyses but seem to be of little stratigraphic significance.

In broadest terms the Oligocene is readily divisible into a lower part typified by plentiful *Globigerina ampliapertura*, a middle part characterized by *Globorotalia opima opima*, and an upper part lacking diagnostic markers; but to define and refine these bold divisions, attention must be paid to other species. Subdivision of the Oligocene into five zones is here recommended (Fig. 6). The datum levels differ markedly in their sharpness of definition and ease of recognition, as explained below.

The few Middle Eocene assemblages examined were not analyzed in detail but could be distinguished readily, in particular by the abundance of large hispid species of *Globorotalia*. Small, sparse examples of these species

reappear in the Oligocene of several sections, where they are attributed to reworking. Presence of any form of *Hantkenina* s.l. or

NORTHERN GULF COREHOLE 29-42 (intermittent cores)	Depth (feet)		5000										4900										4800-4700			
	Core No.		17					16					15					14					13	12	11	
	Sample		14	12	10	6	0	15	12	10	6	0	15	12	10	6	0	15	12	10	6	0	15	0	0	
EOCENE FORMS																										
<i>Hantkenina</i> spp.		X /																								
<i>Globorotalia cerroazulensis</i> subsp.																										
<i>G. c. cerroazulensis</i> s.s.		X /																								
<i>G. c. cocoaensis</i>		○ /																								
<i>G. c. cunialensis</i>		○ / /																								
EO-OLIGOCENE FORMS																										
<i>Pseudohastigerina micra</i>		X / / / X																								
<i>Globorotalia increbescens</i>		X X X X X X X X ○ X																								
<i>Globigerina ampliapertura</i>		○ ○ ○ ○ ○ ● ● ● ● ●																								
LARGE GLOBIGERINAS																										
<i>G. eoacaena</i>		○ ● ● ● ○ ○ ● ○ ● ○ ○ X ○ ⊕ X																								
<i>G. venezuelana</i>		X X ○ X ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ● ● ●																								
<i>G. tripartita</i>		○ X ○ ● ○ ○ ○ ○ ○ ○ ○ ○ X X ○ X X / X X X ● ●																								
<i>G. linaperta</i> s.s.		○ ○																								
<i>G. corpulenta</i>		X / X X / / / / / X ○ / ⊕ ○ X																								
<i>G. gortanii</i>		? X / X X X X X X ○ ⊕ X																								
SMALL GLOBIGERINAS																										
<i>G. "praebulloides"</i>		○ ○ ○ ○ ● ○ ○ ○ ○ ● ○ ○ ○ ○ ○ ● ● ● ● ● ● ● ○ ○ ○																								
<i>G. "occlusa"</i>		/ X / X X X X X X X X ● ● ● ● ● ● ●																								
<i>G. "ouachitensis"</i>		/ / X X X X X X X X																								
<i>G. angustumbilicata</i>		X X X / / / / X X X X X X ○ ○ ○ ○ ○ ○ ○ ○ ○ ○																								
<i>G. angulisuturalis</i>		○ ● ● ● ● ●																								
<i>G. ciproensis</i>		/ ○ ● ● ● ● ● ○ / / / /																								
OLIGO-MIOCENE FORMS																										
<i>Cassigerinella chipolensis</i>		/ / /																								
<i>Catapsydrax unicavus</i>		○ ○ ○ ○ ○ X X X X X X X X X X / X /																								
<i>Globorotalia opima nana</i>		/ / X X X / X X X X / X X X X X X X X X																								
<i>G. opima opima</i>		?																								
<i>G. postcretacea</i>		/ / X / X / ○ ○ ○ X X X ○																								
<i>G. siakensis</i>		X ○ ● ● ○ ○ ● ● ●																								
<i>G. "obesa"</i>		/ /																								
<i>G. kugleri</i> s.l.		/ /																								
<i>G. kugleri</i> s.s.		○ /																								
<i>G. peripheroronda</i>		?																								
<i>Globoquadrina altispira globularis</i>		X ○ ○ ○ ○ / / / ○																								
<i>G. altispira</i> aff. <i>altispira</i>		○																								
<i>Globigerinoides quad. primordius</i>		○ X X X X ○																								
<i>quadrilobatus</i> s.l.		/ X X																								
<i>Globigerinita</i> spp.		○ X X																								
Z O N E S		Grt. cerroaz.		Ps. micra		Globigerina ampliapertura					Grt. opima opima					Globigerina ciproensis					Grt. ? kugleri					
ASSIGNED AGE		EOC.		O L I G O C E N E																				M I O		

FIG. 2. Planktonic foraminifera in samples from Corehole 29-42 in the northern Gulf of Mexico.

NORTHERN GULF COREHOLE 32-45 (intermittent cores)	5700			5600			5500			5400					
	Depth (feet)		Core No.	17		15		14		13		12		11	
	7	5		15	12	10	5	15	12	10	5	15	12	10	5
Sample	7	5	15	12	10	5	15	12	10	5	15	12	10	5	
EOCENE FORMS															
<i>Globigerinatheka</i> spp.	X	X	X												
<i>Hantkenina</i> spp.	X	X	/	/	/	/									
<i>Globorotalia cerroazulensis</i> subsp.	X	X	X	X	X	/									
Hispid globorotalias (tiny)			/	/	/	X									
EO-OLIGOCENE FORMS															
<i>Pseudohastigerina micra</i>	X	•	•	•	•	/									
<i>Globorotalia increbescens</i>		/	/	/	/	X	/	X	/	X	/	X	/	X	
<i>Globigerina ampliapertura</i>		/	/	/	/	•	•	•	•	•	•	•	•	•	
LARGE GLOBIGERINAS															
<i>G. eocaena</i>	X	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>G. venezuelana</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
<i>G. tripartita</i>	X	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>G. linaperta</i> s.s.	X	/	/	/	/	X	X	X	X	X	X	X	X	X	
<i>G. corpulenta</i>	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
<i>G. gortanii</i>	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
<i>G. sellii</i>														/ X /	
SMALL GLOBIGERINAS															
<i>G. "praebulluloides"</i>	⊕	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>G. "occlusa"</i>	⊕	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>G. "ouachitensis"</i>	⊕	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>G. angustiumbilicata</i>															
<i>G. angulisuretalis</i>															
<i>G. ciproensis</i>															
OLIGO-MIOCENE FORMS															
<i>Cassigerinella chipolensis</i>															
<i>Catapsydrax unicavus</i>	X	•	•	•	•	•	•	•	•	•	•	•	•	•	
<i>Globorotalia opima nana</i>															
<i>G. opima opima</i>		/	/	/	/	/	/	/	/	/	/	/	/	/	
<i>G. postcretacea</i>															
Z O N E S	Indefinite			<i>Pseudohast. micra</i> ?*			<i>Globigerina ampliapertura</i>			<i>Globorotalia opima opima</i>					
ASSIGNED AGE	EOCENE			OLIGOCENE											

* Zone boundary might fall within Core 15

FIG. 3. Planktonic foraminifera in samples from Corehole 32-45 in the northern Gulf of Mexico. For explanation of symbols, see key on Figure 2.

Globorotalia cerroazulensis distinguishes Eocene from Oligocene faunas.

Detailed study of the Upper Eocene faunal sequence was not an objective of this study beyond establishing a faunal datum coincident with the Eocene-Oligocene boundary. The few cores available substantiated recogni-

tion by earlier authors of two zones, the lower defined by presence of *Globigerinatheka semiinvoluta* and the upper by presence of *Globorotalia cerroazulensis cunialensis* and absence of the genus *Globigerinatheka* (except perhaps for tiny, indeterminate specimens).

Somewhat unexpected and indicative of a

condensed section or even hiatus is variability of the planktonic assemblage recorded in the highest Eocene sample at different localities. A seemingly complete and normal sequence, diagnosed in particular by presence of *Globorotalia cerroazulensis cunialensis*, was noted in Coreholes 15 and 29-42 as well as in the surface sections. In the continuously cored section of Corehole 5B, however, core 30 is Oligocene devoid of Eocene markers, but core 31 represents the lower zone of the Upper Eocene. In Corehole 32-45 the Upper Eocene assemblage in core 16 is rather sparse but suggests the lower zone, whereas less than 50 feet higher core 15 is Oligocene. In Corehole 16-4/4A, Oligocene and Middle Eocene plankton were recorded in successive cores less than 40 feet apart.

A result of inadequate representation of the Eocene-Oligocene boundary is that no useful comment can be made on the sharpness of its definition by ranges of planktonic foraminifera. Blow (1969) and some later authors assert that a sequence of extinctions and evolutionary events serves for recognition of short time increments through the boundary interval. Other authors state or imply that the extinctions of conspicuous taxa were essentially synchronous and define a single datum corresponding to the standard Eocene-Oligocene boundary. The latter, simpler definition matching the faunas available is accepted here, but validity of the alternative concept is not disproved by this study.

The oldest Oligocene assemblages are distinguished by absence of normal-sized specimens of the standard Eocene indices. An exception must be made for diminutive specimens of hispid species of *Globorotalia*, in particular, which have to be attributed to reworking. If specimens of *Cassigerinella chipolensis* can be found, they verify identification of the Oligocene, but this species is far too scarce for use as a zonal index. For this reason its name is dropped from the title usually assigned to the lowest Oligocene interval, which is here called simply the *Pseudohastigerina micra* Zone.

Nominally this basal zone is defined by the upward range of *Pseudohastigerina micra* above the top of the Eocene, but in practice this criterion may be difficult to apply. First, the index is a tiny species requiring intensive

search unless moderately common in a sample. Second, the same Oligocene sections which yield tiny Eocene *Globorotalia* show an anomalously high upward range of *P. micra*, strongly suggestive that reworked Eocene specimens are responsible. The solution adopted is placement of the zonal boundary at the highest level of persistent presence of the index. In a few places, however, it may be better to ignore this zone (Fig. 4).

Presence of *Pseudohastigerina micra* is the sole distinction of the basal zone from the next higher Oligocene interval, namely the *Globigerina ampliapertura* Zone. Above its first appearance in the Upper Eocene, the distinctive name fossil of this zone persists in the low Oligocene faunas and generally is accompanied by somewhat scarcer specimens of its close relative *Globorotalia increbescens*. Its extinction is abrupt and might well be used to define the top of the zone, following Bolli (1957), but we prefer to use the level of first appearance of *Globigerina angulisuturalis*, arbitrarily following Blow (1969) and Postuma (1971). Levels of first appearance of indices are reputedly more reliable for defining stratigraphic datum-levels than are extinctions, although in the present instance ecological factors may influence recorded ranges.

Approximately but not precisely as *Globigerina ampliapertura* disappears from the assemblages, *Globorotalia opima opima* appears and persists as a conspicuous species through the middle segment of the Oligocene. This is the obvious name fossil for the corresponding zone, but, as can be seen on the distribution charts, both its upper and lower limits are unstable relative to other taxa that display a fixed pattern. The presumption introduced by W. H. Blow (1969, p. 217, 353) is that the large nominate subspecies developed from the small, long-ranging *G. opima nana* in areas and at times of specially favorable ecological conditions. Consequently, formal definition of the base of the *G. opima opima* Zone must be based on another index; the datum chosen is the level of first appearance of *Globigerina angulisuturalis*.

In all four coreholes yielding samples from this interval, *Globigerina angulisuturalis* was recorded as appearing abruptly and not by evolution from a similar but four-chambered form (*G. anguliofficialis* Blow, 1969). The

latter is present and was initially recorded separately in the faunal analyses, but for lack of stratigraphic utility it was subsequently absorbed as merely a variant of *G. angulitaturalis*. Also noteworthy is the recorded appearance of *Globigerina ciproensis* abruptly at almost precisely the same level as *G. angulitaturalis*. This level is generally slightly higher than the extinction of *G. ampliaper-*

tura.
 The top of the *Globorotalia opima opima* Zone is defined by last appearance of the index as a common and persistent element of the faunas. Presence of sparse and sporadic individuals at higher levels is ignored for zonal purposes. A more rigid criterion would be desirable.
 The Oligocene above extinction of *Glob-*

ATLANTIC SLOPE COREHOLE 5/5B (continuous cores)	Depth (feet)		1650								1600																			
	Core No.		31				30				29				28				27				26				25			
	Sample		B	A	F	E	D	B	A	E	D	B	A	D	B	E	D	B	E	D	B	E	D	B	E	D	B	E	D	B
Eocene Forms																														
SMALL																														
1	<i>Globigerinatheka</i> spp.	X	o					X	?	X																				
2	<i>Hantkenina</i> spp.	X	X																											
<i>Globorotalia cerroazulensis</i> subsp.																														
3	<i>G. c. pomeroli</i>	o	X																											
4	<i>G. c. cerroazulensis</i> s.s.	o	X																											
5	<i>G. c. cocoaensis</i>		X																											
6	<i>G. c. cunialensis</i>																													
7	Hispid <i>Globorotalias</i> (tiny)	X	X	o	o	o	o	●	o	X	X	X	X	o	X	X	X	X	X	X	/	/	/	/	/	/	/	/	/	
EO-OLIGOCENE FORMS																														
8	<i>Pseudohastigerina micra</i>	X	⊕	X	●	o	X	X	X	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
9	<i>Globorotalia increbescens</i>	/	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
10	<i>Globigerina ampliapertura</i>	X	o	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
LARGE GLOBIGERINAS																														
11	<i>G. eocaena</i>	o	o	X	X	X	X	X	X	X	X	/	X	/	X	/	X	X	X	X	X	X	X	X	X	X	X	X	X	
12	<i>G. venezuelana</i>	o	o	X	X	X	X	o	o	●	●	/	/	X	X	X	o	o	o	o	o	X	o							
13	<i>G. tripartita</i>	o	o	X	X	X	o	o	●	●	●	o	o	X	X	o	o	o	/	X	X									
14	<i>G. linaperta</i> s.s.		X	X	X	X			X																					
15	<i>G. corpulenta</i>		X	X	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	
16	<i>G. gortanii</i>	/							/																					
17	<i>G. sellii</i>																													
SMALL GLOBIGERINAS																														
18	<i>G. "praebulloides"</i>	o	o	X	●	●	o	o	●	o	o	/	/	o	/	/	o	o	o	o	o	●	●	●	●	●	●	●	●	
19	<i>G. "occlusa"</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
20	<i>G. "ouachitensis"</i>	X	X	X	X	X	X	X	X	X	X	X	X	●	●	o	/	X	o	o	o	●	●	●	●	●	●	●	●	
21	<i>G. angustumbilicata</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
22	<i>G. angulitaturalis</i>																													
23	<i>G. ciproensis</i>																													
OLIGO-MIOCENE FORMS																														
24	<i>Cassigerinella chipolensis</i>																													
25	<i>Catapsydrax unicavus</i>																													
26	<i>C. dissimilis</i>																													
27	<i>Globorotalia opima nana</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
28	<i>G. opima opima</i>																													
29	<i>G. postcretacea</i>																													
30	<i>G. siakensis</i>																													
31	<i>G. "obesa"</i>																													
32	<i>G. kugleri</i> s.l.																													
33	<i>G. kugleri</i> s.s.																													
34	<i>G. peripheroronda</i>																													
35	<i>Globoquadrina altispira globularis</i>																													
36	<i>G. altispira</i> aff. <i>altispira</i>																													
37	<i>Globigerinoides quad. primordius</i>																													
38	<i>G. quadrilobatus</i> s.l.																													
39	<i>Globigerinita</i> spp.																													
Z O N E S		Gtk. semi.	<i>Pseudohastigerina micra</i>								?	<i>Globig. ampl.</i>								<i>Globorotalia opima opima</i>										
ASSIGNED AGE		EOC.	OLIGOCENE																											

FIG. 4A. Planktonic foraminifera in samples from Corehole 5B on the Atlantic slope; cores 25-31, mid-Oligocene to Late Eocene. For explanation of symbols, see key on Figure 2.

orotalia opima opima mostly falls within the *Globigerina ciproensis* Zone, for which faunal characteristics are mainly negative. It contains an assemblage of long-ranging species, especially of *Globigerina*, and lacks taxa distinctive of either the lower Oligocene or the Miocene. The top of the zone is formally defined by appearance of *Globorotalia kugleri* s.s., foreshadowed by sparse and sporadic

primitive forms (*G. mendacis* Blow, 1969; *G. pseudokugleri* Blow, 1969) here referred to as *G. kugleri* s.l. Other forerunners of important Neogene taxa, first seen sparsely near the base of the zone and becoming commoner up-section, are *Globorotalia siakensis*, the earlier forms of *Globoquadrina altispira* (including subspecies *globosa* and *globularis*), and diminutive specimens of *Globigerinita in-*

ATLANTIC SLOPE COREHOLE 5/5B (continuous cores)	Depth (feet)		1550				1500				1450																						
	Core No.		24		23		22		21		20		19		18		17		16		15												
	Sample		F	E	D	B	F	E	D	B	F	E	D	B	F	E	D	B	F	E	D	B	F	E	D	B	F	E	D	B	F	E	D
EOCENE FORMS																																	
1 <i>Globigerinatheka</i> spp.																																	
7 Hispid <i>Globorotalias</i> (tiny)																																	
EO-OLIGOCENE FORMS																																	
8 <i>Pseudohastigerina micra</i>																																	
LARGE GLOBIGERINAS																																	
11 <i>G. eocaena</i>																																	
12 <i>G. venezuelana</i>																																	
13 <i>G. tripartita</i>																																	
15 <i>G. corpulenta</i>																																	
16 <i>G. gortanii</i>																																	
17 <i>G. sellii</i>																																	
SMALL GLOBIGERINAS																																	
18 <i>G. "praebulloides"</i>																																	
19 <i>G. "occlusa"</i>																																	
20 <i>G. "ouachitensis"</i>																																	
21 <i>G. angustiumbilicata</i>																																	
22 <i>G. angulisuaturalis</i>																																	
23 <i>G. ciproensis</i>																																	
OLIGO-MIOCENE FORMS																																	
24 <i>Cassigerinella chipolensis</i>																																	
25 <i>Catapsydrax unicus</i>																																	
26 <i>C. dissimilis</i>																																	
27 <i>Globorotalia opima nana</i>																																	
28 <i>G. opima opima</i>																																	
29 <i>G. postcretacea</i>																																	
30 <i>G. siakensis</i>																																	
31 <i>G. "obesa"</i>																																	
35 <i>Globoquadrina altispira globularis</i>																																	
37 <i>Globigerinoides quad. primordius</i>																																	
39 <i>Globigerinita</i> spp.																																	
Z O N E S																																	
														<i>Globorotalia opima opima</i>							<i>Globigerina ciproensis</i>												
ASSIGNED AGE																																	
OLIGOCENE																																	

FIG. 4B. Planktonic foraminifera in samples from Corehole 5B on the Atlantic slope; cores 15 to 24, Oligocene. Species numbered as on Figure 4A; explanation of symbols on Figure 2.

crusta. Within this interval *Globigerina angulisurealis*, *G. ciperoensis*, and *G. sellii* all dwindle in number, and their disappearance from the fauna is a guide to the top of the zone.

In the two coreholes that penetrated the *G. ciperoensis* Zone the evolutionary appearance of *Globigerinoides quadrilobatus primordius* is recorded just above the extinction of

Globorotalia opima opima, and the genus *Globigerinoides* becomes steadily more abundant and morphologically advanced toward the top of the zone. Empirically this pattern must be accepted as a zonal criterion in the region studied, although it represents a striking departure from the accepted norm.

The first appearance of *Globorotalia kugleri* s.s. is the highest clear-cut datum

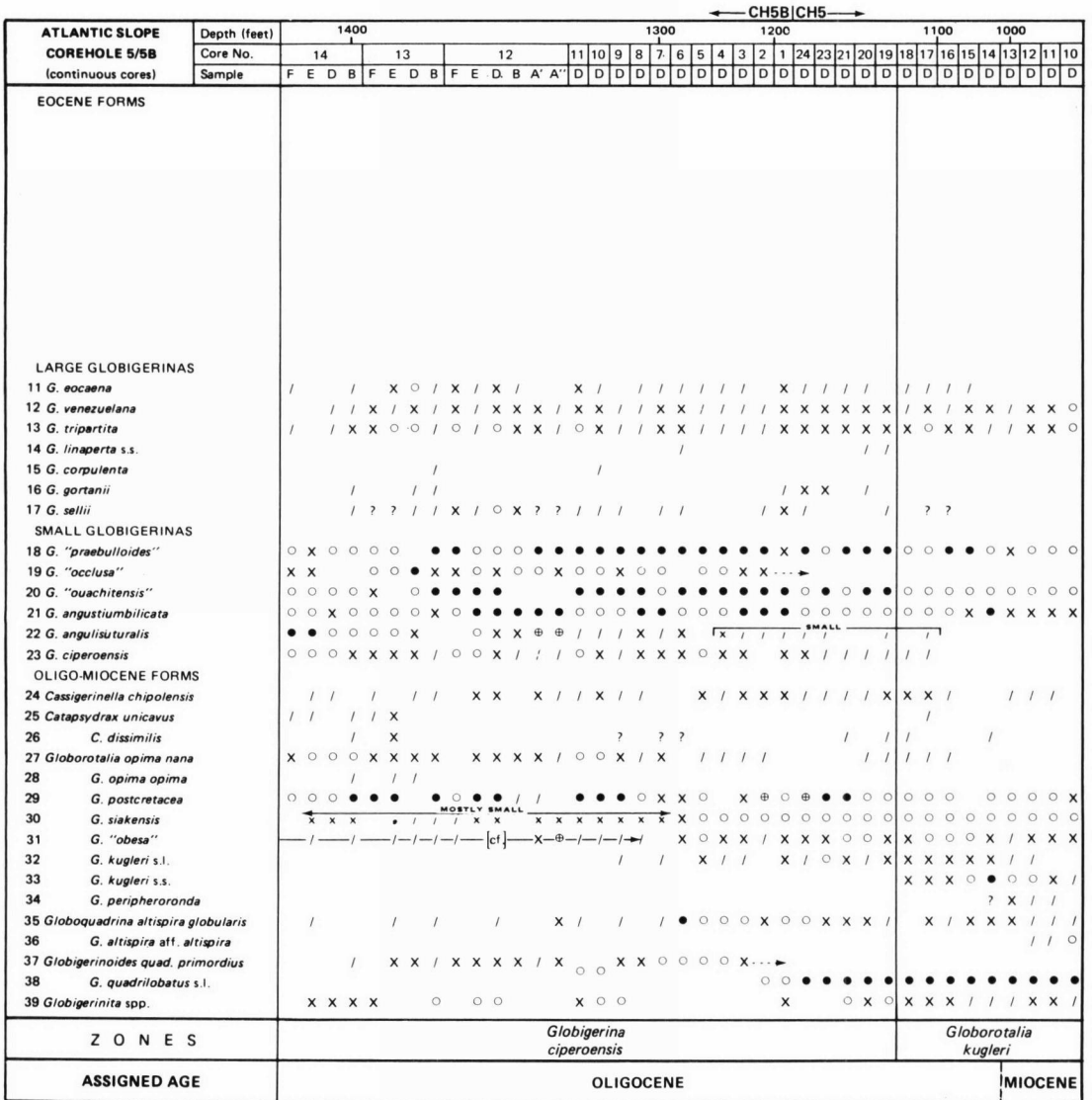


FIG. 4C. Planktonic foraminifera in samples from Coreholes 5 and 5B on the Atlantic slope; cores 10 through 24 of Corehole 5 and cores 1 through 14 of Corehole 5B, Early Miocene (?) and late Oligocene. Species numbered as on Figure 4A; explanation of symbols on Figure 2.

recognized in these studies. The base of the *Globorotalia kugleri* Zone is sharply defined by this datum, but in contrast no easily defined top could be established. The basic difficulty is shortage of evidence inasmuch as the range zone of *Globorotalia kugleri* was sampled in only two coreholes, and in both young Neogene beds lie unconformably on or immediately above it. Specifically, in Corehole 5 *Globorotalia kugleri* was recorded in the highest core available (10), and Exxon Production Research paleontologists reported a Pliocene fauna in core 8; in Corehole 29-42 *G. kugleri* was recorded in cores 13 and 12 and a Miocene-Pliocene fauna in core 10. Possibly cores 9 of Corehole 5 and 11 of Corehole 29-42 represent a post-*kugleri* zone, but the evidence is not firm enough for formal treatment.

Turning to published zonal schemes for a possible solution, we find that Bolli (1957) first used the total range of *Globorotalia kugleri* to define a zone within which the genus *Globigerinoides* first appeared. Blow (1969) recorded similar relative ranges of the taxa but used the *Globigerinoides* Datum as a zonal boundary and gave no formal role to first appearance of *G. kugleri*. Postuma (1971) followed Bolli in defining the base of his *Globorotalia kugleri* Zone by first appearance of the name fossil but approximately followed Blow in applying *Globigerinoides* evolution to subdividing the range zone of the index.

Thus, the suggested solution is to apply the *Globigerinoides* Datum as an upper boundary of our *Globorotalia kugleri* Zone, which seemingly is not wholly represented in our study area. Unfortunately, however, this procedure is inhibited by the abnormally low levels of first appearance of subspecies of *Globigerinoides quadribatus* in the study area. Two distinctive taxa seen only in the highest cores some distance above the *G. kugleri* Datum are *Globoquadrina altispira* aff. *altispira* and *Globorotalia fohsi peripheroronda*. At least tentatively, their appearance provides a substitute for the *Globigerinoides* Datum. For formal purposes, however, use of the range zone of *Globorotalia kugleri* is recommended on the assumption that extinction of the name fossil is as sharply defined in this region as in the many other regions for which there are published records.

Zonal division of this interval ties in directly with placement of the Oligocene-Miocene boundary, which by current convention coincides with the *Globigerinoides* Datum and falls at mid-level within the stratigraphic range of *Globorotalia kugleri*. Inapplicability of the main criterion poses a major problem. Apparently the level of first appearance of either *Globoquadrina altispira* aff. *altispira* or *Globorotalia fohsi peripheroronda*, or both together, serves for identification of top of the Oligocene, but this is based on rather scanty evidence.

ZONATION OF INDIVIDUAL SECTIONS

Atlantic Slope Coreholes 5/5B and northern Gulf of Mexico Coreholes 29-42 and 32-45.—Detailed faunal analyses (Fig. 2-4, 7) illustrate the zonal criteria already discussed.

Atlantic Slope Corehole 15.—This hole (cores 6 to 10—5,081 to 5,204 feet—supplemented by bit scrapings) contributed little to the study because of sparse planktonic assemblages coupled with limited stratigraphic penetration and some confusion in the lower samples (Fig. 7). The residues of cores 6 to 8 are glauconitic and contain siliceous microfossils and benthonic foraminifera in greater abundance than planktonic foraminifera. Their aspect suggests partial solution below the carbonate compensation depth.

The species present, although seldom common, constitute a typical assemblage of the *Pseudohastigerina micra* Zone with the joint presence of *Globorotalia increbescens*, *Globigerina ampliapertura*, and *Pseudohastigerina micra* being the most diagnostic feature. Abnormal but also recorded at the same level in Coreholes 5B and 32-45 is persistent occurrence of tiny hispid species of *Globorotalia* presumed to be reworked from Eocene beds.

Core 9 was not recovered. In the top 29 inches of core 10 the residue changes to fine, subangular sand. Planktonic foraminifera are again scarce but include acute-peripheried subspecies of *Globorotalia cerroazulensis* indicative of Late Eocene age. Bit scrapings supposedly from the same interval yielded an entirely different assemblage of pure white plankton containing such Middle Eocene markers as *Globorotalia lehneri*, *Truncorotaloides rohri*, and species of *Globi-*

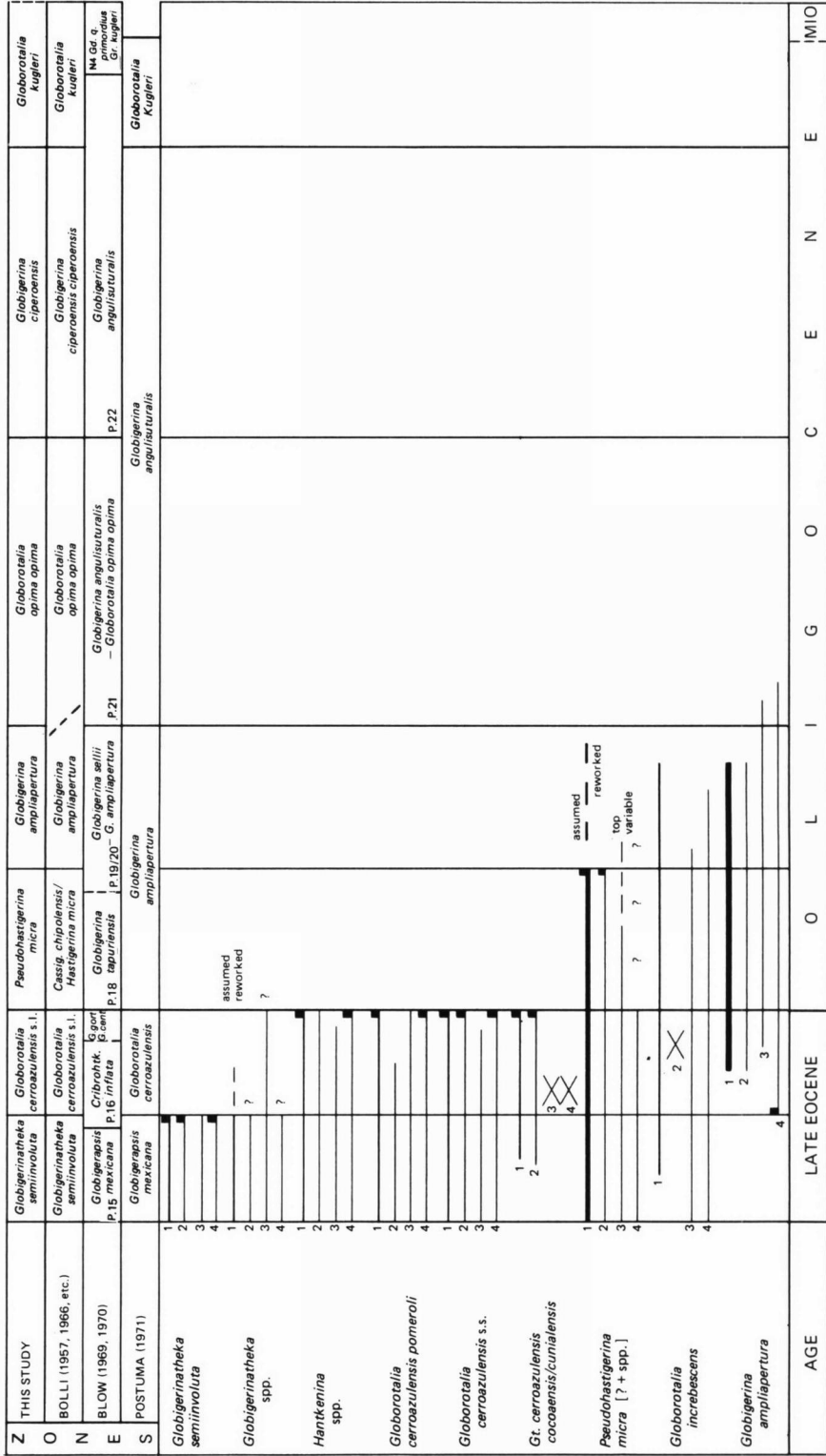


FIG. 5A. Composite range chart showing zonation derived from the present study and published zonations; Eocene to Oligocene index species. Numbers in the left column identify source of range bars: 1, present study; 2, H. M. Boli; 3, W. H. Blow; 4, J. A. Postuma. If a taxon was not recognized by a source, the bar is replaced by X. Solid squares on bars indicate tops and bottoms of ranges applied in formal definition of zones by the indicated source. Dashes indicate sporadic occurrence. For the present study, the thickness of the bars is proportional to the average frequency observed. On this figure, *Globigerinatheka semiinvoluta* = *Globigerinatheka mexicana* of Blow (1969) and of Postuma (1971); *Globigerinatheka* includes *Globigerapsis* of authors; *Hantkenina* includes *Cribrohantkenina* of authors; and *Globorotalia cerroazulensis pomeroli* = *Globorotalia centralis* of authors.

Z	THIS STUDY	<i>Globigerinatheka</i> <i>semirivolata</i>	<i>Globorotalia</i> <i>cerroazulensis</i> s.l.	<i>Pseudohastigerina</i> <i>micra</i>	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globorotalia</i> <i>opima opima</i>	<i>Globigerina</i> <i>ciproensis</i>	<i>Globorotalia</i> <i>kugleri</i>			
O	BOLL (1957, 1966, etc.)	<i>Globigeinatheka</i> <i>semirivolata</i>	<i>Globorotalia</i> <i>cerroazulensis</i> s.l.	<i>Cassig. chipolensis</i> / <i>Hastigerina micra</i>	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globorotalia</i> <i>opima opima</i>	<i>Globigerina</i> <i>ciproensis</i>	<i>Globorotalia</i> <i>kugleri</i>			
N	BLOW (1969, 1970)	<i>Globigerinopsis</i> <i>mexicana</i>	<i>Globorotalia</i> <i>cerroazulensis</i> s.l.	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globorotalia</i> <i>opima opima</i>	<i>Globigerina</i> <i>ciproensis</i>	<i>Globorotalia</i> <i>kugleri</i>			
E		<i>Globigerinopsis</i> <i>mexicana</i>	<i>Globorotalia</i> <i>cerroazulensis</i> s.l.	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globorotalia</i> <i>opima opima</i>	<i>Globigerina</i> <i>ciproensis</i>	<i>Globorotalia</i> <i>kugleri</i>			
S	POSTUMA (1971)	<i>Globigerinopsis</i> <i>mexicana</i>	<i>Globorotalia</i> <i>cerroazulensis</i> s.l.	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globigerina</i> <i>ampliapertura</i>	<i>Globorotalia</i> <i>opima opima</i>	<i>Globigerina</i> <i>ciproensis</i>	<i>Globorotalia</i> <i>kugleri</i>			
	<i>Cassigerinella</i> <i>chipolensis</i>										
	<i>Globorotalia</i> <i>opima opima</i>										
	<i>Globigerina</i> <i>sellii</i>										
	<i>Globigerina</i> <i>ciproensis</i>										
	<i>Globigerina</i> <i>angulisurealis</i>										
	<i>Globorotalia</i> <i>siakensis</i>										
	<i>Globoquadrina</i> <i>arispira</i> subsp.										
	<i>Globigerinoides</i> <i>quadrilobatus</i> <i>primordius</i>										
	<i>Globigerinoides</i> <i>quadrilobatus</i> subsp. (more advanced)										
	<i>Globorotalia</i> <i>kugleri</i> s.l.										
	<i>Globorotalia</i> <i>kugleri</i> s.s.										
	<i>Globorotalia</i> <i>fohsi</i> <i>peripheronada</i>										
	AGE	LATE EOCENE	O	L	I	G	C	E	N	E	IMIO

FIG. 5B. Continued from facing page. Legend as for Figure 5A. On this figure, *Globorotalia siakensis* includes *Globorotalia mayeri* of authors.

gerinatheka. Comparison with data on deeper cores indicates that a labeling error must be assumed.

Northern Gulf of Mexico Corehole 16-4 and Corehole 4A.—Because of limited stratigraphic penetration (cores 1 to 5 at 2,246 to 2,472 feet in Corehole 16-4; cores 1 and 2 at 2,355 to 2,524 feet in Corehole 4A), this section was not analyzed in detail, although it deserves note for containing an outstandingly rich representation of the large Oligocene species of *Globigerina* (Fig. 7).

In downward sequence, Holocene (probably due to contamination) at the top of the highest core gives place to beds diagnosed as the *Globorotalia opima opima* Zone by joint presence of the name species, *Globigerina angulisuturalis*, and *G. ciperensis*. At approximately 2,362 feet within Core 4A-1, disappearance of the latter two species indicates the top of the *Globigerina ampliapertura* Zone, which is further indicated by occurrence below this level of *Globorotalia increbescens*, *Globigerina ampliapertura*, and forms intermediate between them (Fig. 7). *Globorotalia opima opima* remains common down to the base of this core.

The *Pseudohastigerina micra* Zone is identified by presence of its name fossil (almost common at some levels) in the next deeper core (4-4). Joint presence of *Cassigerinella chipolensis* was not observed, although this species was recorded sparsely in higher cores.

The two deeper cores (4-5, 4A-2) are from Eocene clay, which, although not studied in detail, is faunally suggestive of Middle Eocene. Significant taxa noted are species of *Globigerinatheka*, hispid *Globorotalia*, and the more primitive (*pomeroli*-like) subspecies of *Globorotalia cerroazulensis*.

Surface Sections.—Sample sequences from well-known Gulf Coast surface sections were studied but gave disappointing results. Although individual samples are rich in well-preserved planktonic foraminifera, many intervals contained no age-diagnostic indices. Especially above the lower Oligocene, the assemblages are too sparse to be applied in zonation. The corehole samples provide a basis better beyond comparison for establishing stratigraphic ranges.

Separate samplings of the Little Stave Creek section were available, numbered in

terms of Bandy's 1949 scheme. The Eocene-Oligocene boundary is sharply defined in both by abrupt disappearance at the top of the Jackson Formation of all subspecies of *Globorotalia cerroazulensis* (including advanced *cocoensis-cunialensis* forms) and all Hantkeninidae (Locs. 57-60). In the overlying Red Bluff-Mint Spring-Marianna sequence (Locs. 61-67), planktonic assemblages are either sparse or, if reasonably rich, are dominated by long-ranging species. Zonally most significant are *Globigerina ampliapertura*, *Globorotalia increbescens*, and *Pseudohastigerina micra*; the latter is almost common in the base of the Marianna Limestone (Loc. 66).

Two sets of samples were also available from St. Stephens quarry in Alabama, covering the same interval at the base and extending up into the Byram and Chickasawhay formations. Above the Marianna Limestone, however, planktonics are sparse and not zonally diagnostic. One Chickasawhay sample yielded a sandy residue containing sparse plankton as in the Marianna; reworking is suspected. The Marianna also contains *Globigerina ampliapertura*, *Globorotalia increbescens*, and sparse *Pseudohastigerina micra*. In the more marly underlying Yazoo-Red Bluff sequence, the planktonic foraminifera are more abundant, but the composition of the assemblage does not differ basically down through the Shubuta Member. Below this level (top of Pachuta Member) large hantkeninids and advanced subspecies of *Globorotalia cerroazulensis* occur.

In all the surface material studied, no specimens of later Oligocene index species were observed, in particular *Globorotalia opima opima* and *Globigerina angulisuturalis*.

REWORKING

Tiny hispid species of *Globorotalia* recorded in the lower half of the Oligocene in Coreholes 5B, 15, and 32-45 would normally be identified unhesitatingly as Eocene forms. Several colleagues have examined them and confirmed this opinion. Within the same sets of samples, the tiny index *Pseudohastigerina micra* ranges abnormally high above the top of the Eocene, locally reaching the extinction

level of *Globigerina ampliapertura*. This double anomaly is best explained by reworking. It is noteworthy, however, that only diminutive forms are involved. Neither normal-sized species of hispid *Globorotalia* nor specimens of larger Eocene forms (e.g., *Hantkenina*, *Globigerinatheka*, subspecies of *Globorotalia cerroazulensis*) were recorded as allochthonous elements within the Oligocene faunas. A feasible explanation is that the fine, misplaced material represents the extreme tips of turbidite tongues.

Two outcrop samples of the Red Bluff Clay yielded rich microfaunas in which benthonic foraminifera outnumbered planktonic forms. Locality data are given as "Hwy. 84. 10

miles E. of Grove Hill, Ala." and "Ala. Geol. Soc. Field Trip 4, Stop 10, Bed 6." Both assemblages match the Red Bluff faunas already mentioned, but in the Grove Hill sample five specimens of *Hantkenina alabamensis* and two of *Globorotalia cerroazulensis cocoaensis* were noted. The opinion commonly expressed is that presence of such Eocene species in the Oligocene Red Bluff results from reworking. This is a matter for local geologists to decide by evaluation of all lines of evidence; we merely observe that the anomalous specimens do not differ obviously in preservational aspect from the rest of the microfauna.

COMPARISON WITH OTHER ZONATIONS

When planktonic foraminiferal zonation was first applied successfully to stratigraphic correlation on a regional and interregional scale, the concept arose of a single set of circumglobal zones defined everywhere by ranges of the same taxa. Continued study proved that this hope was too idealized. Objective difficulties arose, especially the effects of varying sensitivity of plankton to temperature, resulting in individual distribution patterns related to latitude and paleoclimate. These difficulties were aggravated by subjective aspects in the realm of taxonomy, such as postulation of evolutionary linkages and fine splitting of taxa.

With full recognition of these difficulties, several authors have proposed zonal schemes having wide zonal applicability for marine Tertiary sediments. Representative are those of H. M. Bolli, particularly his Trinidad paper of 1957 and circumglobal summary of 1966 but also several supplementary studies (Toumarkine & Bolli, 1970; Bolli, 1972); W. H. Blow, primarily his voluminous paper of 1969 incorporating earlier work, much of it jointly with F. T. Banner, and also a short paper of 1970 including a modification of the Oligocene zonation; and the manual of J. A. Postuma (1971). Publication dates are somewhat misleading because Blow's magnum opus was essentially complete before 1967, when a summary was presented at the First Planktonic Conference in Geneva, and

Postuma's book is an updated version of a Royal Dutch-Shell manual dating back to 1960.

The zonal divisions, formal criteria, and ranges of significant taxa postulated by these authors are summarized on the accompanying composite range chart (Fig. 5), which includes the corresponding interpretation of the present study. Readily apparent is the good agreement on logical choice of zone boundaries and zonal indices. Datum levels given particular importance, from older to younger, are the extinction of several Eocene lineages, the first appearance of *Globigerina angulisurealis*, extinction of *Globorotalia opima opima*, and appearance of the short-lived *Globorotalia kugleri* s.s. The sources cited indicate less constancy in the ranges of other taxa plotted on the chart. Nevertheless, a sequential pattern of appearances and disappearances is clearly seen, such that a given assemblage of these indices would be assigned to essentially the same portion of the Oligocene no matter which authority might be selected.

The range of *Globorotalia kugleri* is particularly important as a guide to the Oligocene-Miocene boundary. From conferences in 1967 (e.g., Cita, 1968, p. 10-12; Blow, 1969, p. 201, 223-224; Ikebe and others, 1972, p. 50, 68) arose general acceptance that the *Globigerinoides* Datum is the best foraminiferal criterion for recognizing the Oligocene-Miocene boundary and that it is

Age	Zone	Primary datums	Secondary datums
MIOCENE	<i>GLOBOROTALIA KUGLERI</i>	Top of zone not defined; extinction of <i>Globorotalia kugleri</i> presumed applicable here as elsewhere	First appearances of <i>Globoquadrina altispira</i> aff. <i>altispira</i> and <i>Globorotalia tohsi peripheroronda</i>
OLIGOCENE	<i>GLOBIGERINA CIPEROENSIS</i>	First appearance of <i>Globorotalia kugleri</i> s.s.	First appearance of primitive forms of <i>Globorotalia kugleri</i>
	<i>GLOBOROTALIA OPIMA OPIMA</i>	Last appearance of <i>Globorotalia opima opima</i> as a common and persistent component of fauna	
	<i>GLOBIGERINA AMPLIAPERTURA</i>	First appearance of <i>Globigerina angulisuturalis</i>	Extinction of <i>Globigerina ampliapertura</i>
LATE EOCENE	<i>GLOBOROTALIA CERROAZULENSIS</i> s.l.	Extinction of <i>Hantkenina</i> spp. and <i>Globorotalia cerroazulensis</i> subsp.	
	<i>GLOBIGERINATHEKA SEMIINVOLUTA</i>	Extinction of <i>Globigerinatheka semiinvoluta</i>	
		Extinction of numerous Middle Eocene indices	
MIDDLE EOCENE			

FIG. 6. Zonation used in the present study, with primary and secondary datums.

straddled by the *Globorotalia kugleri* Range-zone. The *Globigerinoides* Datum is treated as commensurate with the Miocene *Orbulina* Datum, and both have been regarded by many as exceptionally firm levels in the chronologic sense because each is defined by a distinct phase within an evolutionary lineage.

In the present study the criteria for recognizing the *Globigerinoides* Datum were clearly observed in Coreholes 5/5B and 29-42. In the plexus of small species of *Globigerina*, the form designated *G. "occlusa"* becomes more common and more persistent up-section. Then a very few specimens can be found in which the final chamber carries a tiny secondary aperture at the spiral suture, thus becoming *Globigerinoides quadrilobatus primordius*. These in turn become persistently present and steadily more common until, con-

tinuing up-section, they merge into an abundance of larger and more elaborate forms referable to several subspecies of *Globigerinoides quadrilobatus* (e.g., *quadrilobatus* s.s., *triloba*, *immaturus*, *sacculifer*, *altiapertura*).

It is puzzling, however, that the *Globigerinoides* Datum as defined by these first appearances of *Globigerinoides quadrilobatus primordius* falls much lower in the section than the conventionally accepted level. The key subspecies is recorded at the base of the *Globigerina ciproensis* Zone, well below the first appearance of even the primitive forerunners of *Globorotalia kugleri*. Furthermore, evolution into more advanced types of *Globigerinoides* is established below (see Corehole 5/5B, Fig. 4) or no higher than (see Corehole 29-42, Fig. 2) the level where *Globorotalia kugleri* s.s. first appears.

This anomaly is almost the only notable difference between the present study (already reviewed for this aspect by Lamb & Stainforth, 1976) and the established zonal schemes, but it is a resounding one. The evidence might be doubted were it not that other authors (e.g., Jenkins, 1960; Caralp, Valetton, & Vigneaux, 1965; Anglada, 1971; Cicha, Hagn, & Martini, 1971; Poag, 1972; Alvinerie & others, 1973; Cati, 1974; Groupe Français d'Etude du Néogène, 1974) with various degrees of certainty have recently documented primitive *Globigerinoides* in beds which, on other evidence, must be assigned to the Oligocene (in the *Globigerina ciproensis* Zone or the equivalent *Sphenolithus distentus* and *Sphenolithus ciproensis* nannofossil zones). We have knowledge of such cases in the Caribbean-Gulf Coast region and also in France and Italy, the Carpathians and Alps, Australia, and New Zealand. The sequential pattern of other taxa corresponds so closely in the present study and in published zonations that the abnormality has to be attributed to the range of *Globigerinoides*. In other words, it would be illogical to take the *Globigerinoides* Datum as irrevocably fixed and then seek explanations for the abnormal ranges of *Globorotalia opima opima*, *Globigerina angulituralis*, *Globorotalia kugleri*, and the whole suite of Oligocene species.

For pragmatic purposes failure here of the *Globigerinoides* Datum deprives us of what elsewhere seems simultaneously a sharp zonal boundary and a conveniently clear boundary between Oligocene and Miocene. As a local substitute for this datum, the level of first appearance of *Globoquadrina altispira* aff. *altispira* and *Globorotalia fohsi peripheroronda* is tentatively suggested. These two forms were seen only in the youngest cores examined, and the cited authors agree in showing their earliest appearance at or just above the Oligocene-Miocene boundary. Nevertheless, a zonal boundary is not formally designated pending confirmatory evidence from additional sections. For the present our proposal is to revert to the usage of Bolli (1957, 1966) and recognize the range zone of *Globorotalia kugleri* as a unit straddling the Oligocene-Miocene boundary. Truncation of both the available sections prevented confident detection of the extinction level of

Globorotalia kugleri, but this is a firmly established datum in worldwide zonation.

A deeper significance of diachroneity of the *Globigerinoides* Datum is its seeming disproof of what many regard as an axiom of biostratigraphy, namely that the appearance of each successive morphologic phase in an evolving lineage is a unique event, occurring synchronously throughout the geographic spread of the taxon. This diachroneity has been taken to indicate that joint application of unrelated evolutionary lineages provides the most accurate biochronology, being generally more reliable than use of first and last appearances of arbitrarily chosen species. Blow (1969), for instance, laid particular stress on basing zonal boundaries on evolutionary developments and for this reason he selected several datum levels different from those of earlier authors.

		Northern Gulf Coreholes				Atlantic Slope	
		16-4	16-4A	29-42	32-45	5/5B	15
O L I G O C E N E	<i>Globorotalia kugleri</i> Zone			4681 ↑ 4696 ↓ 4741 ↑ 4820		951 ↑ 1012 ↓ 1086	
	<i>Globigerina ciproensis</i> Zone			4865 ↑ 4880		1460	
	<i>Globorotalia opima opima</i> Zone	2246 ↑ 2348		4925 ↑ 4940	5391 ↑ 5467		
	<i>Globigerina ampliapertura</i> Zone		2355 ↑ 2370	4987 ↑ 5002	5514 ↑ 5586	1610	
	<i>Pseudohastigerina micra</i> Zone	2395 ↑ 2410		5045 ↑ 5060	5635 ↑ 5650	1630 ↑ 1658	5081 ↑ 5126
	<i>Globorotalia cerroazulensis</i> Zone					hiatus	5189 ↑ 5204
	<i>Globigerinatheka semiinvoluta</i> Zone				5697 ↑ 5777	1658	
MIDDLE EOCENE	2457 ↑ 2549+	2509 ↑ 2524			1670 ↑ 1700	5267 ↑ 5653	
		Cored interval ↓					

FIG. 7. Summary of zonal positions of cored intervals in northern Gulf of Mexico and Atlantic slope coreholes. Numbers indicate depths in feet.

The broad validity of the axiom is supported by many examples in all families of planktonic foraminifera. Nevertheless, the evolution of *Globigerinoides* from *Globigerina* is a demonstrable exception, not being fixed in time. The simplest explanation is that the diagnostic feature (i.e., appearance of supplementary dorsal apertures) was not a genetic development, as are comparable features in most lineages, but a functional response to environmental change. In a detailed review of the *Globigerinoides quadrilobatus* complex, Banner and Blow (1965) already ascribed its variability to both ecologic and genetic factors. For open-sea denizens the prime ecologic factor is temperature; hence the further suggestion made independently by Jenkins (1973) and Seiglie (1973) is reasonable, that the development of *Globigerinoides* was symptomatic of warming after the worldwide cooling episode that characterized the Oligocene.

This evaluation of the *Globigerinoides* anomaly leads to the concept that seemingly discrepant ranges reported for Oligocene taxa by different authors may simply reflect temperature-control producing inconsistencies of distribution. An obvious example is the first appearance of *Globorotalia opima opima* variously recorded as preceding, coinciding with, or following the extinction of *Globi-*

gerina ampliapertura (Blow, 1969, p. 216-218). Furthermore, contrary to the usual American pattern, at some European localities *Globigerina ampliapertura* s.l. persists as late as *Globorotalia opima opima* (Cicha, 1970; Cati, 1974). The closely related *Globigerina ciperoensis* and *Globigerina augulisuturalis* appear abruptly at a mid-Oligocene level in the study area, whereas elsewhere the former is recorded back into the earliest Oligocene and the latter is linked to older species by transitional forms. Further examples of local anomaly are the near-absence of *Catapsydrax dissimilis* and the early appearance of *Globigerinita incrusta* in the study area.

In modern studies of Pliocene-Pleistocene sequences the variability of local ranges of species is an accepted fact related to paleoclimatic cycles and applicable to interpretative biostratigraphy (e.g., Ingle, 1973; Stainforth & others, 1975). Cifelli (1969), Berggren (1969b), and many others have presented evidence that the Oligocene was markedly colder than the Late Eocene and Early Miocene. By analogy, the recommendation emerges that interpretation of the Oligocene assemblages would benefit from application of the statistical and other special biogeographical techniques developed in Pleistocene studies.

NOMENCLATURE AND STRATIGRAPHIC DISTRIBUTION OF TAXA

NOMENCLATURAL AND PHOTOGRAPHIC TREATMENT

The following comments express our opinions on differentiation of taxa for the pragmatic purpose of zoning and correlating Oligocene sediments. We have tried to follow recognized authorities but admit openly to inability in certain cases, notably by failure to discern the sequential evolution and other relationships postulated by our late friend Walter Blow. The reason may well be limitations of our powers of perception, but we prefer the explanation that ecologic factors play a greater role in the distribution and variability of the Oligocene plankton than was suspected until quite recently. Blow himself (1969) observed the variable range of *Globorotalia opima opima* and deduced an ecologic cause, and other evidence of paleoclimatic influences has been noted already.

Species-group taxa are reviewed here by genera in alphabetical order. In keeping with the pragmatic concept of this report, synonymies of the species reviewed are not given in any detail. Those concerned with this aspect should consult cited references, in particular Blow (1969) and Stainforth and others (1975).

Stratigraphically significant taxa are illustrated by SEM photographs of selected specimens considered to be representative of each form as seen under a binocular microscope at normal magnifications. Loss of the final chamber is evident in some specimens but is no hindrance to recognizing the distinctive features of the taxa in question. Contrary to usual practice in reports illustrated by SEM photographs—namely, use of a different specimen for each aspect depicted—each taxon is here represented by differently oriented views of single specimens. This advantageous pro-

cedure results from the manipulative skill of Mr. Hardie Turnbull, whose services were kindly made available by Imperial Oil Ltd. in Calgary. Trochospiral taxa are illustrated by self-explanatory standard views (dorsal, ventral, peripheral) plus a few supplementary views explained in the captions. A uniform magnification of $\times 78$ is used for all except the smallest forms, some of which are illustrated at $\times 130$. An exception is *Globorotalia cerroazulensis cocoaensis* Cushman, illustrated by SEM photographs of three different specimens taken at $\times 96$ to $\times 130$ by Mr. Ralph Hockett of Exxon Production Research Company in Houston.

Genus CASSIGERINELLA Pokorný, 1955

Cassigerinella chipolensis (Cushman & Ponton, 1932)

Plate 8, figure 1

This diminutive species is generally rare in this area and, consequently, not formally applicable to zonation although apparently confined to post-Eocene beds. Increased abundance was recorded in the *Globorotalia opima opima* Zone in Corehole 5B but not in other sections. The distinctive shell surface of well-preserved specimens of this species is characterized by scattered tuberculate pores (Pl. 8, fig. 1a). Without comment in the text, Jenkins and Orr (1972, pl. 1, fig. 7) illustrated this feature.

Genus CATAPSYDRAX Bolli, Loeblich, & Tappan, 1957

The name *Catapsydrax* is applied to globigerine forms with a simple umbilical bulla and a distinctly cancellate surface, the latter feature distinguishing species of *Catapsydrax* from the smooth-shelled *Globigerinita*.

Catapsydrax unicavus Bolli, Loeblich, & Tappan, 1957

Catapsydrax unicavus persists through the Late Eocene and all the Oligocene sections studied; thus it has negligible value for zonation.

Catapsydrax dissimilis (Cushman & Bermúdez, 1937)

An important index in most published

Oligocene-Miocene zonation, *C. dissimilis* is unaccountably scarce and is represented only by occasional isolated specimens, although these few are entirely typical of the species.

Genus GLOBIGERINA D'Orbigny, 1826

Globigerina ampliapertura Bolli, 1957

Plate 3, figure 3

Globigerina ampliapertura is readily distinguished from other species (particularly *Globigerina venezuelana*) by its arched and partly extraumbilical aperture indicative of close relationship to *Globorotalia increbescens* as shown by Blow and Banner (1962, fig. 12b). Specimens with a lower aperture, which some might refer to *Globigerina prasaepis* Blow (1969), are present through its whole range. *G. ampliapertura* consistently disappears only a short distance below the first appearance of *Globigerina angulicosturalis*; thus, its extinction level serves as a secondary datum in the zonal scheme of this report.

Globigerina linaperta Group (Large Forms)

Plate 1, figures 1-4; Plate 2, figures 1-4;
Plate 3, figures 1-2

Except for *Globigerina ampliapertura*, just reviewed, the large *Globigerina* typical of Eocene to Oligocene deep-water assemblages are regarded as a plexus centered on *Globigerina linaperta* Finlay (1939). The subject has been discussed in detail elsewhere (Stainforth, 1974; Stainforth & others, 1975) and so is treated summarily here. Classification of the group is based solely on chamber arrangement and gross form of the test. Details of shell texture, aperture, and umbilicus play almost no part in the recommended division into species. For the record, the shell of well-preserved specimens is coarsely reticulate, and for this sole reason the plexus has been assigned by some authors to the genus *Subbotina* Brotzen and Pozaryska (1961) as redefined by Loeblich and Tappan (1964). In our opinion, however, assignment of widely differing species to *Subbotina* merely on the basis of a single feature, reticulation, tends to impede rather than facilitate stratigraphic applications and the understanding of evolutionary relationships.

Forms within the plexus intergrade in multiple ways from the central form so that nomenclature of individual specimens is difficult. The preferred solution is to name only the main extremes of morphologic variation. Forms transitional between these extremes are not formally named.

The central form, *Globigerina linaperta* Finlay (1939) (Pl. 1, fig. 1), has a low, compact coil in which each successive chamber is approximately equal in size to the whole of the preceding test, so that the last whorl has 3½ to 4 chambers visible dorsally but only 3 visible ventrally. In gross aspect it is neither compressed nor elevated, and chambers are neither strongly appressed nor loosely attached.

Radiating from this central form are variants in which the main trends of change are:

1. Flat to low-spined as *G. linaperta* but developing a lower rate of increase in chamber size, resulting in forms with 4 to 5 chambers in last whorl, all visible in both dorsal and ventral aspects (Pl. 1, fig. 2). These are assigned to *Globigerina eocaena* Gümbel (1868), a senior synonym of *Globigerina yeguaensis* Weinzierl and Applin (1929).

2. As *G. eocaena* but further differing from *G. linaperta* in appreciable elevation of the spire. In intermediate forms the raised chambers form a central turret projecting above the chambers of the outer whorl. These fall within *Globigerina corpulenta* Subbotina (1953) (Pl. 1, figs. 3-4), a species whose variability is well represented by the 17 figures of 6 specimens provided by Subbotina (1953, 1971). Loftier forms (Pl. 2, figs. 2, 3) belong to *Globigerina gortanii* (Borsetti, 1959), which is a senior synonym of *Globigerina turritilina* Blow and Banner (1962), whose division into subspecies is not supported by our study.

3. Initially as *G. linaperta* but growth of later chambers achieved by ventral prolongation more than by radial growth, resulting in a taller, subglobular test (Pl. 2, fig. 1). This is *Globigerina venezuelana* Hedberg (1937).

4. As *G. venezuelana* but chambers increasing in size more rapidly, resulting in a form with only 3 chambers per whorl (Pl. 2, fig. 4). This is *Globigerina tripartita* Koch (1926), a senior synonym of *Globigerina rohri* Bolli (1957). In the present study numerous examples were noted of a high-spined variant

(Pl. 3, fig. 1) intermediate between *G. tripartita* and *G. corpulenta*.

5. As *G. tripartita* but rate of increase of chamber size further accelerated, resulting in forms with a hemispherical final chamber (Pl. 3, fig. 2). These are assigned to *Globigerina sellii* (Borsetti, 1959), a senior synonym of *Globigerina clarae* Bermúdez (1960) and *Globigerina oligocaenica* Blow and Banner (1962). *Globigerina sellii* is further characterized by spikes on its ventral surface.

In study of natural assemblages representing the *Globigerina linaperta* group, juveniles (diameter of less than 0.4 mm) should be disregarded. The distinctive features of each species appear in its adult chambers (i.e., in specimens at least 0.5 to 0.6 mm in diameter). Rarity of such large specimens in washed residues (because of ecologic inhibition, non-preservation, or fragility) reduces their potential value as stratigraphic indices. A further difficulty arises from the common presence of specimens with stunted or malformed (kummerform) final chambers. Only trivial importance should be attached to these aborted chambers, and they should not be confused with functional bullas.

As regards stratigraphic and zonal significance, the conclusion reached in this study is that only hazy linear patterns are discernible in the slow evolution of the *G. linaperta* plexus from Middle Eocene through Oligocene time. The threefold reason for this is that (1) in the Late Eocene and indefinitely into the Oligocene most of the variants coexisted, (2) some forms whose first appearance has been applied to zonation are in fact defined on such elusive and transitional characters that their routine identification is impractical (e.g., *Globigerina tapuriensis* Blow & Banner, 1962), and (3) the readily recognized, late-appearing forms (notably *G. gortanii* and *G. sellii*) occur too sparsely and sporadically to serve as zonal indices.

Details of occurrence of the seven principal species are included on the faunal charts (Figs. 2-4). Differences in the distribution patterns of these species, presumably reflecting both ecologic and preservational aspects, hinder summarization; in broad terms the distribution of individual species is as follows.

G. linaperta s.s.—Seldom common. Locally confined to the Eocene but elsewhere re-

corded up through the *Globorotalia opima opima* Zone.

G. eoacaena.—May be common to abundant up through the *Globorotalia opima opima* Zone, then sparse but still present to the top of the Oligocene.

G. venezuelana and *G. tripartita*.—These two have virtually the same distribution pattern, both being present in almost every sample from Upper Eocene to Lower Miocene; commonly the most conspicuous species in the planktonic assemblage.

G. corpulenta and *G. gortanii*.—For practical purposes these can be treated jointly, both being recorded sporadically and seldom as common from Upper Eocene to Upper Oligocene.

G. sellii.—Recorded very sparsely in the *Globorotalia opima opima* Zone and more consistently in the overlying *Globigerina ciperensis* Zone.

Small Pentacamerate Species of *Globigerina*

Plate 7, figures 1-3

Small pentacamerate species of *Globigerina* (diameters typically 0.2 to 0.3 mm) were recognized by several authors as a diagnostic element of American Oligocene microfauas but were erroneously assigned to *Globigerina concinna* Reuss (1850). Their taxonomy was formalized by proposal of the species *Globigerina ciperensis* Bolli (1954) and its later subdivision into the three subspecies—*Globigerina ciperensis* s.s., *G. ciperensis angulisurealis* Bolli (1957), and *G. ciperensis angustiumbilitata* Bolli (1957). Later authors have generally treated the three forms as separate species, and this procedure is adopted here mainly to avoid the use of long trinomials. *Globigerina ciperensis* and *G. angulisurealis* are certainly closely related, as indicated by plentiful intermediate specimens, despite their assignment to unrelated lineages by Blow and Banner (1962) and Blow (1969).

Globigerina ciperensis Bolli (1957) (Pl. 7, fig. 1) is typified by its large umbilicus and the geometric regularity of the low spire of globular chambers. In the material examined this form was recorded as first appearing close to the extinction level of *Globigerina ampliapertura*, then persisting as a conspicuous element

up through the *Globorotalia opima opima* and *Globigerina ciperensis* zones, but becoming abruptly sparser and disappearing from the assemblages near the level of first appearance of *Globorotalia kugleri*.

Globigerina angulisurealis Bolli (1957) (Pl. 7, fig. 2) appears so consistently just above the extinction level of *Globigerina ampliapertura* that its incipience is used formally to define the base of the *Globorotalia opima opima* Zone, above which level its distribution is almost identical with that of *G. ciperensis*. Blow (1969) postulated evolutionary development of *G. angulisurealis* from a similar but tetracamerate species, which he named *Globigerina anguliofficialis*. In the present study the latter form was observed but only within the recorded range of normal *G. angulisurealis*.

Globigerina angustiumbilitata Bolli (1957) (Pl. 7, fig. 3) is persistent and generally plentiful through the entire Late Eocene to Early Miocene interval, so that it has no biostratigraphic utility in the present context. Many specimens differ from *G. ciperensis* only in their smaller umbilici, so that a subspecific relationship might be postulated, but others differ gradationally from the norm and appear to link it with such distinct planktonic species as *Globorotalia postcretacea* and *Globigerina quinqueloba*. Comparable difficulty of delimiting *G. angustiumbilitata* was mentioned by Asano, Ingle, and Takayanagi (1968) and Berggren (1969a, p. 147-148).

Small Tetracamerate Species of *Globigerina*

Plate 6, figures 1-4

Abundant at all levels are small species of *Globigerina* comparable in size to the pentamerous *Globigerina ciperensis* group but differing in their quadrate mode of coiling, which results from more rapidly increasing size of successive chambers. Within this group individuals can readily be selected with sufficient differences to justify their treatment as separate species, but closer study reveals intergradational forms linking the extremes (cf. Kiesel, Lotsch, & Trümper, 1969). In short, this is another plexus comparable to the *Globigerina linaperta* group, although more limited in its variability; a similar approach to its nomenclature is warranted.

Choice of names for the variants presents a problem because many have been applied and authors have been inconsistent in their usage. Nevertheless, an attempt was made in the present study to find a concrete solution because several modern authors have claimed to discern evolutionary trends applicable to Paleogene zonation. Blow (1969), in particular, retaining the nomenclature of Blow and Banner (1962), assigned distinct ranges to six Paleogene species or subspecies within this group (*gnaucki*, *leroyi*, *occlusa*, *officinalis*, *ouachitensis*, *praebulloides*), as well as to numerous homeomorphs in the Neogene. In the more recent literature, exemplified by detailed reports on materials from the Deep Sea Drilling Project, these small forms receive scant attention.

Deliberately ignoring published studies, we attempted to divide this group into readily recognizable variants. An immediate conclusion was that trifling variation in tightness of coiling or in posture of the final chamber could produce disproportionately large differences in the umbilicus or aperture or both, which for this reason were adjudged unsuitable features to apply to speciation. Consequently, we base division on the gross form of the spire, placing prime emphasis on the rate of size increase of the adult chambers and attaching secondary significance to elevation and other features of the spire. The outcome was recognition of five variants that, although intergradational to each other, could be identified expeditiously.

The next step should have been to identify them with published species, but this was not achieved with any degree of certainty. Authors have varied between narrow and broad definition of species (Subbotina, 1953, 1971, for example, figured seven distinct forms as *G. officinalis*) and in their choice of diagnostic criteria. Blow and Banner (1962) and Blow (1969) in addition emphasize the very features (aperture and umbilicus) that we regard as least reliable. They also attach importance to shell surface, but SEM photographs reveal that this is governed as much by preservational history as by genetics of the individual. The theme could be expanded by reference to the classifications of Bandy, Bolli, Poag, and many others, but enough has been said to show how subjective has been the treatment

of these small species of *Globigerina*. Without further discussion, we now indicate the basis used to define the species shown on the accompanying charts.

In all forms, a nucleus no longer than 0.2 mm is observable; this consists of an indistinct knot of chamberlets followed by two better defined chambers set at right angles, each approximately semicircular as viewed dorsally. The aperture is a simple arch over the umbilicus and may carry a light rim or lip. For purposes of discussion names are applied as follows to four distinguishable variants, but in part we regard them as convenient labels rather than formal designations of taxa.

Globigerina "ouachitensis" Howe and Wallace (1932) (Pl. 6, fig. 2).—Slow rate of increase in size of adult chambers. Last two chambers may be subequal or the last may be smaller.

Globigerina "praebulloides" Blow (1959) (Pl. 6, fig. 1).—Adult chambers increase in size regularly, successively occupying more than a third but less than half the area of test as viewed dorsally.

Globigerina occlusa Blow and Banner (1962) (Pl. 6, fig. 4).—Similar to *G. "praebulloides"* but chambers increase in size somewhat more rapidly. Final chamber commonly as large as whole preceding test and may appear elongate.

Globigerina sp. indet.—Chamber sequence as in *G. "ouachitensis"* but coil slightly elevated and tighter so that final chamber is partly tucked under nuclear portion, producing an impression of tricamerate coiling. Distinctive enough to put on record but stratigraphically unimportant.

Globorotalia obesa Bolli (1957) (Pl. 6, fig. 3).—Forms similar to *Globigerina "praebulloides"* in dorsal aspect, but coil slightly looser, hence more quadrate. Aperture swiveled to an atypical position almost or completely extraumbilical. Name used with misgivings although Jenkins (1971, p. 127, 141) also hints at a linkage between *Globorotalia obesa* and *Globigerina "praebulloides."*

As a group, small tetracamerate species of *Globigerina* are abundant through the Late Eocene to Early Miocene interval, but we could discern little chronologic significance in their distribution pattern. Such intergradation with pentacamerate forms as exists (e.g., be-

tween *G. "ouachitensis"* and *G. angustiumbilicata*) was reiterative in character and is not diagnostic of any specific interval. In summary:

1. *Globigerina "praebulloides"* and *G. "ouachitensis"* occur persistently through the whole interval studied, and are generally common to abundant. Patchiness seen on the charts probably results from variable preservation.

2. *Globigerina occlusa* is initially scarce and sporadic, becoming common to abundant only near the top of the *Globorotalia opima opima* Zone and on up through the *Globigerina ciperoensis* Zone. By development of a small dorsal aperture, this form gives rise to *Globigerinoides quadrilobatus primordius*, of which the earliest specimens appear at the base of the *Globigerina ciperoensis* Zone.

3. *Globorotalia obesa* is represented by such sparse and sporadic examples in the lower Oligocene that these might better be treated as teratoid individuals. Within the upper half of the *Globigerina ciperoensis* Zone, however, and on up into the Miocene this form becomes a persistent element in the faunas.

4. *Globigerina* sp. indet. (as described herein) is generally scarcer than other variants but nevertheless was recorded in fair abundance locally at all levels from the Upper Eocene to the *Globorotalia kugleri* Zone.

Genus GLOBIGERINATHEKA Brönnimann, 1952

[Emended Proto Decima & Bolli, 1970]

Plate 5, figures 7-8

Excellent specimens of *Globigerinatheka* were seen in Middle Eocene cores, but representation of this genus is poor in the Upper Eocene of the coreholes studied. Most specimens are too small or too poorly preserved for ready identification in the scheme of Bolli (1972). On Plate 5, figures 7a and 7b are different views of a bullate specimen referred to *G. tropicalis* (Blow & Banner, 1962); figure 8 depicts *G. semiinvoluta* (Keijzer, 1945) identifiable by its smoothly orbiform test interrupted by lunate apertures of which one is visible in profile at upper right. The genus is regarded as an index for the Eocene,

abnormally small specimens noted in the lower Oligocene of Corehole 5B being preferably regarded as reworked from the Eocene.

Genus GLOBIGERINITA Brönnimann, 1951

Globigerinita incrusta Akers, 1955

Plate 8, figure 3

This diminutive species is scarce to common in Corehole 5B upward from the middle of the *Globigerina ciperoensis* Zone and in Corehole 29-42 in the pre-Miocene portion of the *Globorotalia kugleri* Zone. Most specimens are typical in possessing a rectangular bulla with only four openings, but some resemble *G. ambitacrena* (Loeblich & Tappan, 1957) in presence of multiple infra-laminal openings.

Globigerinita incrusta has a wide reputation as an index of Neogene age (e.g., Blow, 1969; Jenkins, 1971). Its presence in the Oligocene is an abnormality comparable with the unusually early appearance of *Globigerinoides* in the study area.

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides quadrilobatus primordius Blow & Banner, 1962

Plate 6, figure 5

Small tetracamerate species of *Globigerina* are abundant in the interval studied. The variant assigned to *Globigerina occlusa* becomes plentiful in the upper part of the *Globorotalia opima opima* Zone and higher. In the basal part of the *Globigerina ciperoensis* Zone careful search reveals specimens differing in presence of a small but well-formed supplementary aperture located on the final chamber at the spiral suture. These clearly belong to *Globigerinoides quadrilobatus primordius* as defined and described by Blow and Banner (1962, p. 115, 136-138). Continuing up-section, this primitive representative of *Globigerinoides* is seen more persistently and it becomes common at the level of first appearance of forerunners of *Globorotalia*

kugleri. At approximately the same level, larger and more elaborate forms appear, assignable to various subspecies of *Globigerinoides quadrilobatus* s.l.

***Globigerinoides quadrilobatus* (d'Orbigny, 1840) s.l.**

Plate 6, figure 6

Globigerinoides quadrilobatus primordius maintains the same small size as its immediate ancestor, *Globigerina oclusa*. The offshoots that developed from it prolifically in the later part of the *Globigerina ciperensis* Chronozone are, however, considerably larger and have two or more dorsal apertures. The specimen chosen to illustrate this group is assignable to *G. q. quadrilobatus*, but other subspecies are well represented, in particular *G. q. triloba* and *G. q. sacculifer*.

Genus GLOBOQUADRINA Finlay, 1947

***Globoquadrina altispira globularis* Bermúdez, 1960**

Plate 5, figure 2

This small, usually four-chambered subspecies ranges from the Upper Eocene to Lower Miocene. It is grossly similar to *Globigerina eoacena* but differs in looser coiling and, especially, in presence of "apertural teeth" (i.e., a tapering prolongation of each adult chamber into the umbilicus). Blow (1969) considered this subspecies to be the immediate common ancestor of *G. altispira altispira* (Cushman & Jarvis, 1936) and *G. a. globosa* Bolli (1957). It differs from the former subspecies in the more globular shape of its chambers and from the latter subspecies in having fewer chambers in the adult. Although also recorded very sparsely in the middle Oligocene, the first persistent appearance is in the upper part of the *Globigerina ciperensis* Zone of late Oligocene age.

***Globoquadrina altispira* aff. *altispira* (Cushman & Jarvis, 1936)**

Plate 5, figure 3

This form differs from the typical *G.*

altispira altispira, known from high in the Lower Miocene, by its lower trochospiral profile and less appressed chambers. It is recorded only in the higher part of the *Globorotalia kugleri* Zone, appearing at approximately the same level as *Globorotalia fohsi peripheroronda*. Because the *Globigerinoides* Datum is abnormally low and therefore not applicable in its usual key role, use of first appearance of *Globoquadrina altispira* aff. *altispira* is suggested as a substitute guide to the Oligocene-Miocene boundary in this area.

***Globoquadrina?* spp. indet.**

Isolated individuals reminiscent of the quadrate forms centered on *Globoquadrina dehiscens* (Chapman, Parr, & Collins, 1934) were observed at scattered levels in the top three zones, but we prefer to dismiss them as teratoid specimens of *Globigerina venezuelana*.

Genus GLOBOROTALIA Cushman, 1927

***Globorotalia cerroazulensis* (Cole, 1928) subsp.**

Plate 3, figure 5; Plate 4, figures 3-6; Plate 7, figure 7

The treatment of *Globorotalia cerroazulensis* by Toumarkine and Bolli (1970) is accepted. Evolution is discernible from the subspecies *G. c. pomeroli* Toumarkine and Bolli (1970), with round periphery, through the nominate subspecies, with shoulders, to *G. c. cocoaensis* Cushman (1928), with an acute periphery. In the present study these forms served jointly to distinguish Eocene from Oligocene assemblages. The most advanced form of the lineage, the lenticular and lightly keeled subspecies *G. c. cunialensis* Toumarkine and Bolli (1970), was recorded only at the top of the Eocene in sections where the Eocene-Oligocene contact appears to be normal and was absent where a hiatus or condensed section was suspected. The evidence accords with acceptance of this form elsewhere as an index to latest Eocene age.

***Globorotalia increbescens* (Bandy, 1949)**

Plate 3, figure 4

A quadrate species characterized by its

gaping aperture set at a right angle to the curve of the spire, *Globorotalia increbescens* is recorded rather sparsely in the Upper Eocene and lower Oligocene to the same extinction level as its offspring, *Globigerina ampliapertura*, which is distinguished by an obliquely placed aperture and generally more globose test.

Globorotalia opima opima Bolli, 1957

Plate 4, figure 2

The two subspecies of *Globorotalia opima* are similar in their coiling parameters, the prime difference being size. Nevertheless, distinction is generally easy as transitional specimens are rare. Large specimens of *Globorotalia siakensis* may resemble *G. o. opima* but generally exhibit a slower rate of increase of chamber size, resulting in 5 to 6 rather than 4 to 5 chambers in the outer whorl. In our opinion, the paratype figured by Bolli (1957) is more representative of a natural population of *Globorotalia o. opima* than is his holotype.

Globorotalia o. opima is diagnostic of Oligocene age and has appropriately been selected as name fossil of the middle zone in modern subdivisions. Nevertheless, its stratigraphic limits are indefinite relative to those of other zonal indices. On empirical evidence three successive events in the early Oligocene were the extinctions of *Pseudohastigerina micra* and of *Globigerina ampliapertura* and the first appearance of *Globigerina angulisurealis*, but recorded levels of local first appearance of *Globorotalia o. opima* vary appreciably relative to these fixed datum levels. The reason is presumed to be ecologic control of development of the large *G. o. opima* from the small *G. o. nana*. By analogy, ecologic control of the upper stratigraphic limit of *G. o. opima* is a logical supposition but not readily verified because no clear-cut extinctions or arrivals of unrelated foraminiferal taxa are recorded at a comparable level. For lack of anything better, the extinction level is therefore used to define a zonal boundary.

Globorotalia opima nana Bolli, 1957

Plate 4, figure 1

Globorotalia opima nana is present from

Upper Eocene through the Oligocene but differs in abundance from one corehole to another. In Coreholes 5-B and 29-42 it tends to be scarce or absent where *G. opima opima* is present, but this relationship is not seen in Corehole 32-45.

Globorotalia postcretacea (Myatliuk, 1950)

Plate 8, figure 2

A very small pentacamerate species characterized by its compressed, almost discoidal test and bluntly rounded margin, *Globorotalia postcretacea* is a characteristic element of Oligocene microfauas. It is of negligible stratigraphic utility because of its long range, into the Late Eocene and presumed Early Miocene. Test morphology becomes more variable in its upper range, including forms comparable to *Globigerina angustiumbilitata* except for their smooth, matte surface.

Globorotalia obesa Bolli, 1957

Plate 6, figure 3

Note prior discussion of small tetracamerate species of *Globigerina*.

Globorotalia siakensis LeRoy, 1939

Plate 5, figure 1

The test is a thick, discoidal trochospire with 5 to 7 chambers in its last whorl. Main differences from *Globorotalia opima opima* are its looser coil and more numerous chambers, lower diameter-to-thickness ratio, and commonly oblique setting of dorsal sutures. Nevertheless, intraspecific variation within both species is such that peripheral variants may be difficult to distinguish. *Globorotalia mayeri* of authors is included in this taxon.

Globorotalia siakensis first appears near the level of extinction of *G. opima opima*. Initially represented by sparse and small specimens, it becomes steadily more plentiful up-section and is a conspicuous element in upper Oligocene and Lower Miocene assemblages.

Globorotalia kugleri Bolli, 1957 s.l.

Plate 7, figure 4-6

At an indefinite level above the extinction of *Globorotalia opima opima*, near the first persistent occurrence of *Globorotalia siakensis*, a new *Globorotalia* starts to appear. It is a small species (diameter 0.2 to 0.3 mm) with no obvious ancestors in the middle Oligocene faunas. The delicate discoidal test is typified by 6 to 7 chambers in the outer whorl and intercameral sutures that are radial to oblique on the dorsal side, radial on the ventral side. The periphery is evenly rounded and the surface finely cancellate. From the somewhat variable initial forms arises a more constant species in which the margin is asymmetrically offset toward the flattened dorsal surface and the dorsal intercameral sutures are all obliquely recurved. Its asymmetry is more readily apparent under a binocular microscope than in SEM photographs.

The planoconvex form is assigned to *Globorotalia kugleri* Bolli s.s. as emended by Blow (1969), and the level of its evolutionary appearance defines the boundary between the *Globigerina ciperoensis* and *Globorotalia kugleri* zones. In both coreholes that penetrated the interval, this datum is sharply defined. In further agreement with Blow (1969), we include the earlier, more discoidal forms in *Globorotalia kugleri* s.l.; but no stratigraphic utility is perceptible in his separation of two primitive subspecies (*mendacis*, *pseudo-kugleri*). Their presence is diagnostic of the upper portion of the *Globigerina ciperoensis* Zone, but the level of first appearance is too indefinite to serve as a zonal datum.

***Globorotalia fohsi peripheroronda* Blow & Banner, 1966**

Well-known and employed as a worldwide zonal index in the Miocene is the earliest form of the *Globorotalia fohsi* lineage, now given the trivial name *peripheroronda* in replacement of *barisanensis*, the name earlier used extensively but erroneously. It grossly resembles *Globorotalia kugleri* but in the outer whorl has fewer chambers (5 to 6), which increase progressively in size. In the present study this species would be unimportant were it not for

the anomalously low position of the *Globigerinoides* Datum here. As a substitute guide to the Oligocene-Miocene boundary the earliest appearance of *Globorotalia fohsi peripheroronda* (jointly with *Globoquadrina altispira* aff. *altispira*) appears satisfactory.

Hispid species of *Globorotalia*

Plate 8, figures 4, 5

Conspicuous in microfaunas of the lower Paleogene are several groups of *Globorotalia* characterized by a hispid to spinose shell. These are distinctive enough to be referred to the subgenus *Acarinina* Subbotina (1953) by several authors. Wholesale extinction of these forms is an accepted criterion for recognizing the top of the Middle Eocene. In the present study, for instance, large and plentiful specimens were observed in Middle Eocene cores, whereas the only *Globorotalia* in the Late Eocene assemblages are the smooth-shelled species already reviewed, referred by some authors to the subgenus *Turborotalia* Cushman and Burmúdez (1949).

In view of this established pattern, it came as a surprise to encounter hispid species of *Globorotalia* in certain intervals assigned unhesitatingly to the Oligocene. The preferred explanation is a form of reworking such that only fine-grained allochthonous (Eocene) material is present. Evidence in support of this interpretation includes the following: (1) There is no record of hispid species of *Globorotalia* as a normal element in Oligocene assemblages. (2) The size of specimens is consistently small (ca. 0.2 mm) relative to that of average Middle Eocene specimens (0.3 to 0.5 mm). (3) Also present are the equally small Eocene-Oligocene index *Pseudohastigerina micra*, here ranging above its normal stratigraphic limit, and sparse, very small specimens assigned to the Eocene genus *Globigerinatheka*. (4) As recorded in Corehole 5B, the pattern of initial abundance of these tiny forms at the base of the Oligocene, dwindling away indefinitely toward complete disappearance within the *Globorotalia opima opima* Zone, is contrary to the abrupt extinctions generally recorded for these taxa. (5) Absent from the same intervals is any suggestion of

reworking from the Eocene of such larger species as normal-sized *Hantkenina*, subspecies of *Globorotalia cerroazulensis*, or representative benthonic foraminifera.

Genus GLOBOROTALOIDES Bolli, 1957

Globorotaloides suteri Bolli, 1957

Plate 5, figures 4, 5

Specimens of *Globorotaloides suteri* were recorded at all levels through the Oligocene, varying in frequency from one corehole to another. The species was not plotted on the distribution charts because it has no stratigraphic utility in the present context and, furthermore, is so variable that its separation from other taxa (e.g., *Catapsydrax unicavus*) is difficult.

Genus HANTKENINA Cushman, 1925

Hantkenina spp.

Plate 5, figure 6

The genus *Hantkenina* is mainly represented by single chambers of broken specimens. The figured specimen is one of the few fairly complete examples observed. Probably the commonest species is *Hantkenina alabamensis* Cushman (1925) but *H. primitiva* Cushman and Jarvis (1929) and *H. longispina*

Cushman (1925) may also be present. Detached chambers of a more inflated hantkeninid are suggestive of *Cribohantkenina inflata* (Howe, 1928), but no specimen was found carrying the accessory apertures characteristic of that species.

Presence of species of *Hantkenina* is a reliable guide to Eocene age with the sole exception of some outcrop samples of the Oligocene Red Bluff Clay. This anomaly has been discussed in the literature (cf. Jones, 1958) and is generally attributed to reworking.

Genus PSEUDOHASTIGERINA Banner & Blow, 1959

Pseudohastigerina micra (Cole, 1927)

Plate 8, figure 6

Pseudohastigerina micra (assigned to the genus *Globanomalina* Haque, 1956, by some modern authors, cf. Loeblich & Tappan, 1964) is smaller than most taxa selected as zonal indices but is readily recognized by its planispiral coiling. Generally it has a well-defined stratigraphic range, and we follow several authors (Blow & Banner, 1962; Bolli, 1966) in applying its extinction level to define the lowest zone in the Oligocene. Nevertheless, in some sectors the utility of this datum is vitiated by presence through the lower Oligocene of a reworked Eocene microfauna containing *P. micra*.

CONCLUSIONS

Submarine cores provide assemblages of Oligocene planktonic foraminifera infinitely richer than those obtained from classic outcrop localities in the Gulf Coast region.

The material should therefore be fully illustrative of evolutionary patterns and lineages. Without recourse to statistical analysis, we conclude, however, that very few cases of evolutionary development are so sharply defined as to be applicable to zonation. The single example used in definition of a zonal boundary is the evolution of *Globorotalia kugleri* s.s. from more primitive subspecies. Other examples are useful guides to strati-

graphic level but not employed in formal zonation: for instance, appearance in the highest Eocene of the carinate subspecies *Globorotalia cerroazulensis cunialensis*; development within the Oligocene of *Globorotalia opima opima* from *G. o. nana*, conspicuous but influenced by ecologic factors; and evolution within the *Globoquadrina altispira* lineage here accepted as a guide to the Oligocene-Miocene boundary.

Morphologic development from *Globigerina oclusa* to the simple *Globigerinoides quadrilobatus primordius* and on to the complex group of *G. q. quadrilobatus* is clearly

recorded, but the *Globigerinoides* Datum thus defined occurs at an appreciably lower (older) level than elsewhere recorded. Other interrelationships of taxa postulated by Blow and Banner (1962), Blow (1969), and others either were not observed or had a different stratigraphic connotation. The suggested reason is a greater effect of paleoclimatic factors on distribution patterns of Oligocene plankton than has generally been considered the case. A clear example is the abrupt appearance within the Oligocene in this area of *Globigerina angulisuturalis* and its close relative *G. ciproensis*. Elsewhere they are recorded, respectively, as evolving from an ancestor (*G. anguliofficialis*) that ranged back into the Late Eocene and as first appearing (supposedly by evolution from *G. ouachitensis*) within the Late Eocene. Comparable inter-regional discrepancies of range are well documented among temperature-sensitive taxa in the Pleistocene and confidently attributed to paleoclimatic fluctuations.

In broad terms, and to a great extent in detail, the five natural divisions of the Oligocene in the study area coincide with those of existing zonal schemes (e.g., Bolli, 1966; Blow, 1969; Postuma, 1971). In upward sequence the zones are conveniently named for *Pseudohastigerina micra*, *Globigerina ampliapertura*, *Globorotalia opima opima*, *Globigerina ciproensis*, and *Globorotalia kugleri*; only the last named is the range-zone of its name fossil. A minor departure from established practice is rejection of first appearance of *Cassigerinella chipolensis* as a datum coincident with the Eocene-Oligocene boundary because that taxon is too sparsely recorded for acceptance here as a zonal index.

The main discrepancy encountered is the

low position in this area of the *Globigerinoides* Datum. Whether defined as the level of earliest individuals referable to the *primordius* form or of abrupt proliferation of the genus *Globigerinoides*, the datum falls here within the *Globigerina ciproensis* Zone, whereas its conventional placement is within the overlying range-zone of *Globorotalia kugleri*.

Local anomalies in the form of hiatuses or condensed sections hinder study of the Eocene-Oligocene boundary here, but its main criterion is abrupt extinction of prominent Eocene taxa such as the hantkeninids and *Globorotalia cerroazulensis* s.l. Presence of the carinate subspecies *G. c. cunialensis* typifies the highest Eocene. *Cassigerinella chipolensis* was not encountered in the Eocene but is far from common in the Oligocene.

The Oligocene-Miocene boundary is conventionally defined by the *Globigerinoides* Datum within the *Globorotalia kugleri* Range-zone, but the study area is anomalous. The suggested local substitute is the level of joint appearance of *Globoquadrina altispira* aff. *altispira* and *Globorotalia fohsi peripheroronda*.

Reworking is suspected only in the lower part of the Oligocene, where in some sections diminutive hispid species of *Globorotalia* of Eocene type occur in some abundance, and *Pseudohastigerina micra* ranges higher than elsewhere. Considered jointly with abnormalities at the Eocene-Oligocene boundary, the reworking suggests turbidity flows associated with eustatism or local uplift at the end of the Eocene. The corehole samples of the Eocene-Oligocene interval represent open-sea, deep-water facies so that hiatuses (as in Corehole 5B) are more readily explained by slumping than by emergence and erosion.

REFERENCES

- Akers, W. H., 1955, Some planktonic Foraminifera of the American Gulf Coast and suggested correlations with the Caribbean Tertiary: *J. Paleontol.*, v. 29, p. 647-664, 3 fig., pl. 65.
- Alvinerie, Jacques, & others, 1973, A propos de la limite oligo-miocène: résultats préliminaires d'une recherche collective sur les gisements d'Escornebéou (Saint-Geours-de-Meremne, Landes, Aquitaine meridionale). Présence de *Globigerinoides* dans les faunes de l'Oligocène supérieur: *Bull. Soc. Geol. Fr.* 15, suppl. 3, p. 75-76.
- Alvinerie, Jacques, & others, 1977, Stratotype et parastratotype de l'Aquitainien: *Com. Fr. Strat.*, Les stratotypes français, no. 4, 105 p., 20 fig., 2 pl.
- Anglada, M. R., 1971, Sur la position du datum à *Globigerinoides* (Foraminiferida), la zone N. 4 (Blow 1967) et la limite oligo-miocène en Méditerranée: *Acad. Sci. (Paris) C. R.*, ser. D., v. 272, p. 1067-1070.
- Anonymous, 1977, IGCP Project 114—Biostratigraphic datum-planes of Pacific Neogene, 2nd Working Group Meeting, Bandung 1977: abstracts and agenda.
- _____, 1978, IGCP Project 114—Biostratigraphic datum-planes of Pacific Neogene, 3rd Working Group Meeting, Stanford 1978, abstracts and program: *Stanford Univ. Publ. (Geol. Sci.)*, v. 14, 65 p., illus.
- Asano, Kiyoshi, Ingle, J. C., Jr., & Takayanagi, Yokichi, 1968, *Globigerina quinqueloba* Natland; Origin and distribution in late Cenozoic of the north Pacific: *Gior. Geol.*, ser. 2, v. 35, pt. 2, p. 217-246, 15 fig.
- Bandy, O. L., 1949, Eocene and Oligocene Foraminifera from Little Stave Creek, Clarke County, Alabama: *Bull. Am. Paleontol.*, v. 32, p. 35-240, 2 fig., p. 5-32.
- Banner, F. T., & Blow, W. H., 1959, The classification and stratigraphic distribution of the Globigerinaceae: *Palaeontology*, v. 2, p. 1-27, 5 fig., pl. 1-3.
- _____, & _____, 1965, *Globigerinoides quadrilobatus* (d'Orbigny) and related forms; Their taxonomy, nomenclature and stratigraphy: *Cushman Found. Foraminiferal Res. Contrib.*, v. 16, p. 105-115, 19 fig., pl. 16.
- Berggren, W. A., 1969a, Paleogene biostratigraphy and planktonic Foraminifera of northern Europe: 1st Int. Conf. Planktonic Microfossils, Geneva 1967, *Proc.*, v. 1, p. 121-160, 7 fig., 8 pl.
- _____, 1969b, Rates of evolution in some Cenozoic planktonic Foraminifera: *Micropaleontology*, v. 15, p. 351-365, 13 fig.
- _____, 1978, Recent advances in Cenozoic planktonic foraminiferal biostratigraphy, biochronology and biogeography; Atlantic Ocean: *Micropaleontology*, v. 24, p. 337-370, 26 figs.
- _____, & Aubert, Jane, 1976, Late Paleogene (Late Eocene and Oligocene) benthonic foraminiferal stratigraphy and paleobathymetry of Rockall Bank and Hatton-Rockall Basin: *Micropaleontology*, v. 22, p. 307-326, 3 fig., 4 pl.
- Bermúdez, P. J., 1960, Contribución al estudio de las Globigerinidea de la región Caribe-Antillana (Paleocene-Reciente): *Bol. Geol. (Venezuela)*, Spec. Pub. 3 (3d Cong. Geol. Venezolano, Caracas 1959, Mem. 3), p. 1119-1393, 20 pl.
- Bizon, Germaine, & Müller, Carla, 1979a, Remarks on the Oligocene/Miocene boundary based on results obtained from the Pacific and Indian Ocean: 7th Int. Congr. Mediterranean Neogene, Athens 1979, *Ann. Geol. Pays Hell.*, spec. vol., p. 101-111, 2 fig.
- _____, & _____ (eds.), 1979b, Report of the working group on micropaleontology: 7th Int. Congr. Mediterranean Neogene, Athens 1979, *Ann. Geol. Pays Hell.*, spec. vol., p. 1335-1364, 1 fig.
- Blow, W. H., 1959, Age, correlation, and biostratigraphy of the upper Tucuyo (San Lorenzo) and Pozón formations, eastern Falcon, Venezuela: *Bull. Am. Paleontol.*, v. 39, p. 67-251, pl. 6-19.
- _____, 1969, Late Middle Eocene to recent planktonic foraminiferal biostratigraphy: 1st Int. Conf. Planktonic Microfossils, Geneva 1967, *Proc.*, v. 1, p. 199-422, 43 fig., 54 pl.
- _____, 1970, Validity of biostratigraphic correlations based on the Globigerinacea: *Micropaleontology*, v. 16, p. 257-268.
- _____, & Banner, F. T., 1962, The Mid-Tertiary (Upper Eocene to Aquitanian) Globigerinacea; in F. E. Eames & others, *Fundamentals of mid-Tertiary stratigraphical correlation*: p. 61-151, fig. 6-20, pl. 8-17, Cambridge University Press.
- _____, & _____, 1966, The morphology, taxonomy and biostratigraphy of *Globorotalia barisanensis* LeRoy, *Globorotalia fohsi* Cushman and Ellisor, and related taxa: *Micropaleontology*, v. 12, p. 286-302, 4 fig., 2 pl.
- Bolli, H. M., 1954, Note on *Globigerina concinna* Reuss, 1850: *Cushman Found. Foraminiferal Res. Contrib.*, v. 5, p. 1-3, 4 fig.
- _____, 1957, Planktonic Foraminifera from the Oligocene-Miocene Cipero and Lengua formations of Trinidad, B.W.I.: *U.S. Nat. Mus. Bull.* 215, p. 97-123, fig. 17-21, pl. 22-29.
- _____, 1966, Zonation of Cretaceous to Pliocene marine sediments based on planktonic Foraminifera: *Bol. Inf. Asoc. Venez. Geol. Min. Pet.*, v. 9, p. 3-32. [Also correction sheet.]
- _____, 1972, The genus *Globigerinatheka* Brönnimann: *J. Foraminiferal Res.*, v. 2, p. 109-136, 84 fig., 7 pl.
- Bolli, W. H., Loeblich, A. R., Jr., & Tappan, Helen, 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae: *U.S. Nat. Mus. Bull.* 215, p. 3-50, fig. 1-9, pl. 1-11.
- Borsetti, A. M., 1959, Tre nuovi foraminiferi planctonici dell'Oligocene Piacentino: *Gior. Geol.*, ser. 2, v. 27, p. 205-212, 1 fig., 1 pl.
- Borsetti, A. M., & others, 1979, Biostratigraphy and absolute ages of the Italian Neogene: 7th Int. Congr. Mediterranean Neogene, Athens 1979, *Ann. Geol. Pays Hell.*, spec. vol., p. 183-197, 2 fig.
- Brönnimann, Paul, 1951, *Globigerinita naparimaensis* n. gen., n. sp., from the Miocene of Trinidad, B.W.I.: *Cushman Found. Foraminiferal Res. Contrib.*, v. 2, p. 16-18, 14 fig.
- _____, 1952, *Globigerinoita* and *Globigerinatheka*, new genera from the Tertiary of Trinidad, B.W.I.: *Cushman Found. Foraminiferal Res. Contrib.*, v. 3, p. 25-28, 3 fig.

- Brotzen, Fritz, & Pozaryska, Krystina, 1961, Foraminifères du Paléocène et de l'Eocène inférieur en Pologne septentrionale; remarques paléogéographiques: *Rev. Micropaleontol.*, v. 4, p. 155-166, 1 fig., 4 pl.
- Caralp, Michell, Valetton, Simon, & Vigneaux, Michel, 1965, Les foraminifères pelagiques du Tertiaire terminal sud-aquitain: *Acad. Sci. (Paris) C. R.*, v. 261, p. 3431-3434. [English transl. *Bol. Inf. Asoc. Venez. Geol. Min. Pet.*, v. 9, p. 61-64, 1966.]
- Cati, Franco, 1974, The Oligo-Miocene boundary in the Mt. Arligo section (Ozzano dell'Emilia, Bologna): *Gior. Geol.*, ser. 2, v. 39, p. 481-502, 1 fig., pl. 44-47.
- Chapman, Frederick, Parr, W. J., & Collins, A. C., 1934, Tertiary Foraminifera of Victoria, Australia—The Balcombian deposits of Port Phillip, pt. 3: *J. Linn. Soc. London Zool.*, v. 38, p. 553-577, pl. 8-11.
- Charm, W. B., Nesteroff, W. D., & Valdes, Sylvia, 1969, Detailed description of the JOIDES cores on the continental margin off Florida: *U.S. Geol. Surv. Prof. Pap.* 581D, 13 p., 6 fig., 2 pl.
- Cicha, Ivan, 1970, Bemerkungen zur Problematik der stratigraphischen Gliederung des Jungtertiärs: *Mitt. Bayer. Staatssamml. Palaeontol. Hist. Geol.*, v. 10, p. 397-406, 1 fig.
- _____, Hagn, Herbert, & Martini, Erlend, 1971, Das Oligozän und Miozän der Alpen und des Karpaten. Ein Vergleich mit Hilfe planktonischer Organismen: *Mitt. Bayer. Staatssamml. Palaeontol. Hist. Geol.*, v. 11, p. 279-293, 1 fig.
- Cifelli, Richard, 1969, Radiation of Cenozoic planktonic Foraminifera: *Syst. Zool.*, v. 18, p. 154-168, 8 fig.
- Cita, M. B., 1968, Report of the Working Group Micropaleontology: *Gior. Geol.*, ser. 2, v. 35, pt. 2, p. 1-22, 2 fig.
- Cole, W. S., 1927, A foraminiferal fauna from the Guayabal formation in Mexico: *Bull. Am. Paleontol.*, v. 14, no. 51, 46 p., 5 pl.
- _____, 1928, A foraminiferal fauna from the Chapapote formation in Mexico: *Bull. Am. Paleontol.*, v. 14, no. 53, p. 1-32, pl. 1-4.
- Cushman, J. A., 1925, A new genus of Eocene Foraminifera: *U.S. Nat. Mus. Proc.*, v. 66, no. 2567, p. 1-4, pl. 1-2.
- _____, 1927, An outline of a re-classification of the Foraminifera: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 3, p. 1-105, pl. 1-21.
- _____, 1928, Additional Foraminifera from the Upper Eocene of Alabama: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 4, p. 73-79, pl. 10.
- _____, & Bermúdez, P. J., 1937, Further new species of Foraminifera from the Eocene of Cuba: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 13, p. 1-29, pl. 1-3.
- _____, & _____, 1949, Some Cuban species of *Globorotalia*: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 25, p. 26-45, pl. 5-8.
- _____, & Jarvis, P. W., 1929, New Foraminifera from Trinidad: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 5, p. 6-17, pl. 2-3.
- _____, & _____, 1936, Three new Foraminifera from the Miocene Bowden marl of Jamaica: *Cushman Lab. Foraminiferal Res. Contrib.*, v. 12, no. 166, p. 3-5, 6 fig.
- _____, & Ponton, G. M., 1932, The Foraminifera of the Upper, Middle and part of the Lower Miocene of Florida: *Fl. Geol. Surv. Geol. Bull.* 9, p. 7-147, pl. 1-17.
- Drooger, C. W., & others, 1976, The Paleogene-Neogene boundary: *Proc. K. Ned. Akad. Wet. Ser. B*, v. 79, p. 317-329.
- Finlay, H. J., 1939, New Zealand Foraminifera; key species in stratigraphy, no. 2: *Trans. R. Soc. N. Z.*, v. 69, p. 89-128, pl. 11-14.
- _____, 1947, New Zealand Foraminifera; key species in stratigraphy, no. 5: *N. Z. J. Sci. Technol. Sect. B*, v. 28, p. 259-292, 9 pl.
- González Donoso, J. M., & Molina, E., 1978, El corte de Navazuelo (Cordilleras Béticas, Provincia de Granada), posible hipoestratotipo del límite Oligoceno-Mioceno: *Cuad. Geol. Univ. Granada*, no. 8-9, p. 225-240, 5 fig., 2 pl.
- Groupe Français d'Etude du Néogène, 1974, Étude biostratigraphique des gisements d'Escornébéou (Aquitaine meridionale, France): *Doc. Lab. Geol. Fac. Sci., Lyon*, 59, 86 p.
- Gümbel, C. W., 1868 (1870), Beiträge zur Foraminiferenfauna der nordalpinen, älteren Eocängebilde oder der Kressenberger Nummulitenschichten: *Abh. Bayer. Akad. Wiss. Math.-Phys. Kl.*, v. 10, pt. 2, p. 579-730, pl. 1-4.
- Hardenbol, Jan, & Berggren, W. A., 1978, A new Paleogene numerical time scale: *Am. Assoc. Pet. Geol. Stud. Geol.*, no. 6, p. 213-234, 8 fig.
- Haque, A. F. M. M., 1956, The Foraminifera of the Ranikot and the Laki of the Nammal Gorge, Salt Range: *Mem. Pak. Geol. Surv., Paleontol. Pak.*, v. 1, 300 p., 34 pl.
- Hedberg, H. D., 1937, Foraminifera of the middle Tertiary Carapita Formation of northeastern Venezuela: *J. Paleontol.*, v. 11, p. 661-697, pl. 90-92.
- Howe, H. V., 1928, An observation on the range of the genus *Hantkenina*: *J. Paleontol.*, v. 2, p. 13-14, 2 fig.
- _____, & Wallace, W. E., 1932, Foraminifera of the Jackson Eocene at Danville Landing on the Ouachita, Catahoula Parish, Louisiana: *Louisiana Geol. Surv. Geol. Bull.* 2, 118 p., 15 pl.
- Ikebe, Nobuo, & others, 1972, Neogene biostratigraphy and radiometric time scale of Japan—An attempt at intercontinental correlation: *Pac. Geol.*, v. 4, p. 39-78, 8 fig.
- Ingle, J. C., Jr., 1973, Summary comments on Neogene biostratigraphy, physical stratigraphy and paleo-oceanography in the marginal northeastern Pacific Ocean: *Initial Rep. Deep Sea Drilling Project*, v. 18, p. 949-960, 5 fig.
- Jenkins, D. G., 1960, Planktonic Foraminifera from the Lakes Entrance oil shaft, Victoria, Australia: *Micropaleontology*, v. 6, p. 345-371, 10 fig., 5 pl.
- _____, 1971, New Zealand Cenozoic planktonic Foraminifera: *N. Z. Geol. Surv. Paleontol. Bull.* 42, 278 p., 2 fig., 23 pl.
- _____, 1973, The present status and future progress in the study of Cenozoic planktonic Foraminifera: *Rev. Esp. Micropaleontol.*, v. 9, p. 133-146, 4 fig.
- _____, & Orr, W. N., 1972, Planktonic foraminiferal biostratigraphy of the east equatorial Pacific DSDP Leg 9: *Initial Rep. Deep Sea Drilling Project*, v. 9, p. 1059-1193, 9 fig., 41 pl.

- Jones, D. J., 1958, Displacement of microfossils: *J. Sediment. Petrol.*, v. 28, p. 453-467.
- Keijzer, F. G., 1945, Outline of the geology of the eastern part of the Province of Oriente, Cuba (E. of 76° W. L.), with notes on the geology of other parts of the island: *Univ. Geogr. Geol. Meded. Physiogr. Geol. Reeks Utrecht*, ser. 2, no. 6, 238 p., 34 fig., 11 pl.
- Kiesel, Yvonne, Lotsch, Dieter, & Trümper, Erwin, 1969, Planktonic Foraminifera from the Oligo/Miocene of the German Democratic Republic (GDR): 1st Int. Conf. Planktonic Microfossils, Geneva 1967, *Proc.*, v. 2, p. 339-342, 2 pl.
- Koch, R. E., 1926, Mitteltertiäre Foraminiferen aus Bulongan, Ost-Borneo: *Eclogae Geol. Helv.*, v. 19, p. 722-751.
- Lamb, J. L., & Stainforth, R. M., 1976, Unreliability of *Globigerinoides* Datum: *Bull. Am. Assoc. Pet. Geol.*, v. 60, p. 1564-1569, 3 fig.
- LeRoy, L. W., 1939, Some small Foraminifera, Ostracoda and otoliths from the Neogene ("Miocene") of the Rokan-Tapanoeli area, central Sumatra: *Natuurk. Tijdschr. Ned. Indie*, v. 99, no. 6, p. 215-296, pl. 1-14.
- Loeblich, A. R., Jr., & Tappan, Helen, 1957, The new planktonic foraminiferal genus *Tinophodella*, and an emendation of *Globigerinita* Brönnimann: *J. Washington Acad. Sci.*, v. 47, p. 112-116, 1 pl.
- _____, 1964, Sarcodina, chiefly Thecamoebians and Foraminiferida; in Moore, R. C. (ed.), *Treatise on invertebrate paleontology: Protista 2, Part C, 2 v.*, 900 p., 653 fig., *Geol. Soc. Am. & Univ. Kansas Press*, New York & Lawrence.
- Meulenkamp, J. E. (ed.), 1975, Report of the working group on micropaleontology, in J. Senes (ed.), Report on activity of the Regional Committee on Mediterranean Neogene Stratigraphy working groups (1971-1975), p. 10-29, 1 fig. Bratislava.
- Myatliuk, E. V., 1950, Stratigrafiya flishevykh osadkov severnykh Karpat v cveta dannyykh fauny foraminifer: *Tr. Vses. Nauchno-Issled. Geologorazved. Neft. Inst.*, n. ser., v. 51 [Mikrofauna SSSR, sb. 4], p. 225-287, 4 pl. [The stratigraphy of the flysch deposits of the northern Carpathian Mountains according to the foraminiferal faunas.]
- d'Orbigny, A. D., 1826, Tableau méthodique de la classe des céphalopodes: *Ann. Sci. Nat. Paris*, ser. 1, v. 7, p. 95-314, pl. 10-17.
- _____, 1840, Mémoire sur les foraminifères de la craie blanche du bassin de Paris: *Mem. Soc. Geol. Fr.*, v. 4, pt. 1, p. 1-51, pl. 1-4.
- Poag, C. W., 1972, Planktonic foraminifers of the Chickasawhay Formation, United States Gulf Coast: *Micropaleontology*, v. 18, p. 257-277, 5 fig., 1 pl.
- Poignant, Armelle, & Pujol, Claude, 1976, Nouvelles données micropaléontologiques (foraminifères planctoniques et petits foraminifères benthiques) sur le stratotype de l'Aquitainien: *Geobios*, no. 9, p. 607-663, 5 fig., 16 pl.
- _____, & _____, 1979, Les stratotypes du Bordelais (Bassin d'Aquitaine, France); Aquitainien et Burdigalien, le "Sallomacien," leur microfaune et leur position biostratigraphique: 7th Int. Congr. Mediterranean Neogene, Athens 1979, *Ann. Geol. Pays Hell.*, spec. vol., p. 993-1001, 4 fig.
- Poore, R. Z., & Brabb, E. E., 1977, Eocene and Oligocene planktonic foraminifera from the upper Butano Sandstone and type San Lorenzo Formation, Santa Cruz Mountains, California: *J. Foraminiferal. Res.*, v. 7, p. 249-272, 3 fig., 8 pl.
- Pokorný, Valdimír, 1955, *Cassigerinella boudecensis* n. gen., n. sp. (Foraminifera, Protozoa) from the Oligocene of the Zdanice Flysch: *Vestn. Ustred. Ustavu Geol.*, v. 30, p. 136-140, 3 fig.
- Postuma, J. A., 1971, Manual of planktonic Foraminifera: 420 p., illus., Elsevier Publishing Co., Amsterdam.
- Proto Decima, Franca, & Bolli, H. M., 1970, Evolution and variability of *Orbulinoides beckmanni* (Saito): *Eclogae Geol. Helv.*, v. 63, p. 883-905, 51 fig., 4 pl.
- Reuss, A. E., 1850, Neues Foraminiferen aus den Schichten des österreichischen Tertiärbeckens: *Akad. Wiss. Wien Denkschr.*, Math.-Nat. Kl., v. 1, p. 365-390, pl. 46-51.
- Seiglie, G. A., 1973, Revision of Mid-Tertiary stratigraphy of southwestern Puerto Rico: *Bull. Am. Assoc. Pet. Geol.*, v. 57, p. 405-406.
- Stainforth, R. M., 1974, Nomenclature of some large Eo-Oligocene Globigerinas: *Verh. Naturforsch. Ges. Basel*, v. 84, p. 256-264, 1 fig., 2 pl.
- Stainforth, R. M., & others, 1975, Cenozoic planktonic foraminiferal zonation and characteristics of index forms: *Univ. Kansas Paleont. Contrib.*, Artic. 62, 425 p., 213 fig.
- Subbotina, N. N., 1953, Iskopaemye foraminifery USSR: Globigerinidy, Khantkeninidy i Globorotaliidy: *Tr. Vses. Nauchno-Issled. Geologorazved. Neft. Inst.*, n. ser., no. 76, 296 p., 8 fig., 41 pl. [Fossil foraminifers of the USSR; Globigerinidae, Hantkeninidae, and Globorotaliidae.]
- _____, 1971, Fossil Foraminifera of the USSR; Globigerinidae, Hantkeninidae and Globorotaliidae: 321 p., 8 fig., 40 pl., Collet's Ltd., London and Wellingtonborough. [Translation by E. Lees of Subbotina, 1953.]
- Toumarkine, Monique, & Bolli, H. M., 1970, Evolution de *Globorotalia cerroazulensis* (Cole) dans l'Eocene moyen et supérieur de Possagno (Italie): *Rev. Micropaleontol.*, v. 13, p. 131-145, 7 fig., 2 pl.
- Weinzierl, L. L., & Applin, E. R., 1929, The Claiborne formation on the coastal domes: *J. Paleontol.*, v. 3, p. 384-410, pl. 42-44.

EXPLANATION OF PLATES

PLATE 1

FIGURE

1. *Globigerina linaperta* Finlay; specimen from Corehole 5B, core 1,658 to 1,674 feet, Upper Eocene; 1a-c, dorsal, ventral, and peripheral views, $\times 78$.
2. *Globigerina eocaena* Gümbel; specimen from Corehole 5B, core 1,364 to 1,380 feet, Oligocene, *Globigerina ciperoensis* Zone; 2a-c, peripheral, dorsal, and ventral views, $\times 78$.
- 3-4. *Globigerina corpulenta* Subbotina; specimens from Corehole 5B, core 1,626 to 1,642 feet, lower Oligocene, *Pseudohastigerina micra* Zone.—3a-c. Tetracamerate specimen, dorsal, ventral, and peripheral views, $\times 78$.—4a-c. Pentacamerate specimen, ventral, dorsal, and peripheral views, $\times 78$.

PLATE 2

FIGURE

1. *Globigerina venezuelana* Hedberg; specimen from Corehole 5, core 1,012 to 1,027 feet, upper Oligocene?, *Globorotalia kugleri* Zone; 1a-c, dorsal, ventral, and peripheral views, $\times 78$.
- 2-3. *Globigerina gortanii* (Borsetti); specimens from Corehole 5B.—2a-c. Specimen from core 1,658 to 1,673 feet, Upper Eocene, dorsal, peripheral, and ventral views, $\times 78$.—3a-c. Specimen from core 1,626 to 1,642 feet, lower Oligocene, *Pseudohastigerina micra* Zone, peripheral, ventral, and dorsal views, $\times 78$.
4. *Globigerina tripartita* Koch; specimen from Corehole 5B, core 1,532 to 1,548 feet, Oligocene, *Globorotalia opima opima* Zone; dorsal,

ventral, and peripheral view, $\times 78$.

PLATE 3

FIGURE

1. *Globigerina tripartita* Koch; lofty-spined variant with surface somewhat leached, from Corehole 32-45, core 5,697 to 5,712 feet, Upper Eocene; 1a-c, dorsal, peripheral, and ventral views, $\times 78$.
2. *Globigerina sellii* (Borsetti); specimen from Corehole 5B, core 1,364 to 1,380 feet, Oligocene, *Globigerina ciperoensis* Zone; 2a-c, peripheral, dorsal, and ventral views, $\times 78$.
3. *Globigerina ampliapertura* Bolli; smaller than average specimen from Corehole 5B, core 1,642 to 1,658 feet, Early Oligocene, *Pseudohastigerina micra* Zone; 3a-c, dorsal, ventral, and peripheral views; 3d, oblique view accentuating gaping, obliquely oriented aperture; $\times 78$.
4. *Globorotalia increbescens* (Bandy); specimen from Corehole 5B, core 1,642 to 1,658 feet, Early Oligocene, *Pseudohastigerina micra* Zone; 4a-c, oblique, apertural, and dorsal views, $\times 78$.
5. *Globorotalia cerroazulensis pomeroli* Toumarkine and Bolli; specimen from Corehole 5B, core 1,658 to 1,673 feet, Upper Eocene; 5a-c, dorsal, peripheral, and ventral views, $\times 78$.

PLATE 4

FIGURE

1. *Globorotalia opima nana* Bolli; specimen from

Corehole 5B, core 1,658 to 1,673 feet, Upper Eocene; 1a-c, ventral, dorsal, and peripheral views, $\times 78$.

2. *Globorotalia opima opima* Bolli; specimen from Corehole 5B, core 1,610 to 1,628 feet, Oligocene, *Globorotalia opima opima* Zone; 2a-c, dorsal, peripheral, and ventral views, $\times 78$.
3. *Globorotalia cerroazulensis cerroazulensis* (Cole); specimen from Corehole 5B, core 1,658 to 1,673 feet, Upper Eocene; 3a-c, ventral, peripheral, and ventral views, $\times 78$.
- 4-6. *Globorotalia cerroazulensis cocoaensis* Cushman; specimens from Upper Eocene Yazoo Clay at Little Stave Creek, Alabama.—4. ventral view, $\times 96$.—5. Dorsal view, $\times 105$.—6. Peripheral view, $\times 130$.

PLATE 5

FIGURE

1. *Globorotalia siakensis* LeRoy; specimen from Corehole 5, core 1,012 to 1,027 feet, upper Oligocene?, *Globorotalia kugleri* Zone; 1a-c, dorsal, peripheral, and ventral views, $\times 78$.
2. *Globoquadrina altispira globularis* Bermúdez; specimen from Corehole 5, core 1,101 to 1,117 feet, Upper Oligocene, *Globigerina ciperoensis* Zone; 2a, apertural details, $\times 174$; 2b-d, dorsal, ventral, and peripheral views, $\times 78$.
3. *Globoquadrina altispira* aff. *altispira* (Cushman & Jarvis); specimen from Corehole 5, core 951 to 966 feet, Lower Miocene?, *Globorotalia kugleri* Zone; 3a-c, dorsal, peripheral, and ventral views, $\times 78$. Note calcite crystal simulating an apertural tooth in c.
- 4-5. *Globorotaloides suteri* Bolli; specimen from

Corehole 5B, core 1,423 to 1,439 feet, Oligocene, *Globigerina ciperoensis* Zone.—4a, b. Bullate form, ventral and dorsal views, $\times 78$.—5a-c. Globorotaliid form, ventral, dorsal, and peripheral views, $\times 78$.

6. *Hantkenina* sp.; specimen from Corehole 5B, core 1,658 to 1,673 feet, Upper Eocene; $\times 78$.
7. *Globigerinatheka tropicalis* (Blow & Banner); specimen from Corehole 5B, core 1,658 to 1,673, Upper Eocene; 7a, b, ventral and dorsal views, $\times 78$.
8. *Globigerinatheka semiinvoluta* (Keijzer)?; poorly preserved specimen from Corehole 5B, core 1,658 to 1,673 feet, Upper Eocene; $\times 78$.

PLATE 6

FIGURE

1. *Globigerina "praebulloides"* Blow and Banner; specimen from Corehole 29-42, core 4,925 to 4,940 feet, Oligocene, *Globorotalia opima opima* Zone; 1a-c, ventral, dorsal, and peripheral views, $\times 78$.
2. *Globigerina "ouachitensis"* Howe and Wallace; specimen from Corehole 5B, core 1,532 to 1,548 feet, Oligocene, *Globorotalia opima opima* Zone; 2a-c, dorsal, peripheral, and ventral views, $\times 78$.
3. *Globorotalia obesa* Bolli; specimen from Corehole 5, core 1,043 to 1,058 feet, upper Oligocene?, *Globorotalia kugleri* Zone; 3a-c, dorsal, peripheral, and ventral views, $\times 78$.
4. *Globigerina oclusa* Blow and Banner; specimen from Corehole 29-42, core 4,925 to 4,940 feet, Oligocene, *Globorotalia opima opima* Zone; 4a-c, dorsal, ventral, and peripheral views, $\times 78$.
5. *Globigerinoides quadrilobatus primordius*

- Blow and Banner; specimen from Corehole 5B, core 1,423 to 1,439 feet, Oligocene, in basal part of *Globigerina ciproensis* Zone.—5a, c, d, dorsal, ventral and peripheral views, $\times 78$; 5b, dorsal aperture, $\times 195$.
6. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny); specimen from Corehole 5B, core 1,102 to 1,117 feet, upper Oligocene, top of *Globigerina ciproensis* Zone; 6a, oblique peripheral view; 6b-c, ventral and dorsal views; $\times 78$.

PLATE 7

FIGURE

1. *Globigerina ciproensis* Bolli; specimen from Corehole 29-42, core 4,925 to 4,940 feet, Oligocene, *Globorotalia opima opima* Zone; 1a-c, dorsal, peripheral, and ventral views, $\times 78$.
2. *Globigerina angulisuturalis* Bolli; specimen from Corehole 29-42, core 4,925 to 4,940 feet, Oligocene, *Globorotalia opima opima* Zone; 2a-c, dorsal, peripheral, and ventral views, $\times 78$.
3. *Globigerina angustumbilicata* Bolli; specimen from Corehole 5B, core 1,642 to 1,658 feet, lower Oligocene, *Pseudohastigerina micra* Zone; dorsal, peripheral, and ventral views, $\times 78$.
4. *Globorotalia kugleri* Bolli s.l.; specimen of primitive form from Corehole 5B, core 1,193 to 1,208 feet, Oligocene, *Globigerina ciproensis* Zone; 4a-c, dorsal, peripheral, and ventral views, $\times 130$.
- 5-6. *Globorotalia kugleri* Bolli s.s.; specimens from Corehole 5, core 1,012 to 1,027 feet, uppermost Oligocene or lowest Miocene, *Globorotalia kugleri* Zone.—5a-c. Peripheral, ventral, and dorsal views, $\times 130$.—6a, b. Ventral and dorsal views, $\times 130$.

7.

Globorotalia cerroazulensis cunialensis Toumarkine and Bolli; specimen from Corehole 29-43, core 5,045 to 5,060 feet, Upper Eocene; 7a, b, ventral and peripheral views, $\times 78$.

PLATE 8

FIGURE

1. *Cassigerinella chipolensis* (Cushman & Ponton); specimen from Corehole 5B, core 1,364 to 1,380 feet, Oligocene, *Globigerina ciproensis* Zone; 1a, shell surface, $\times 522$; 1b-d, dorsal, peripheral, and ventral views, $\times 130$.
2. *Globorotalia postcretacea* (Myatliuk); specimen from Corehole 5B, core 1,610 to 1,626 feet, lower Oligocene, *Globigerina ampliapertura* Zone; 2a-c, dorsal, peripheral, and ventral views, $\times 130$.
3. *Globigerinita incrusta* Akers; specimen from Corehole 29-42, core 4,805 to 4,820 feet, upper Oligocene, *Globorotalia kugleri* Zone; 3a, b, d, ventral, peripheral, and dorsal views, $\times 130$; 3c, enlargement of bulla, $\times 260$.
- 4-5. *Globorotalia* spp.; specimens from Corehole 5B, core 1,642 to 1,658 feet, lower Oligocene, but presumably reworked from Eocene.—4a-c. Hispid form with blunt periphery, peripheral, dorsal, and ventral views, $\times 130$.—5a, b. Hispid form with acute periphery, peripheral and ventral views, $\times 130$.
6. *Pseudohastigerina micra* (Cole); specimen from Corehole 5B, core 1,642 to 1,658 feet, lower Oligocene, *Pseudohastigerina micra* Zone; 6a, b, oblique and side views, $\times 130$.

