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Planktonic Foraminifera as Index Fossils in Trinidad, West Indies and their value for worldwide Stratigraphic Correlation

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With 1 table in the text

INTRODUCTION

The value of the planktonic Foraminifera as index fossils has become increasingly recognised in the last two decades. Their abundance in marine sediments combined with the short life span of many species makes the planktonic Foraminifera in this respect often superior to benthonic Foraminifera and other micro and macro organisms. Although planktonic Foraminifera are known to have a worldwide distribution in marine sediments from Cretaceous to Present Day, they are, like other organism, confined to environments that fulfill their life requirements. They thrive best in clear marine water, but as a rule avoid turbid and brackish water. The wide geographical distribution of planktonic Foraminifera is, therefore, not so much based on their adaptability for life in widely differing environments as on the fact that the particular environments they prefer cover a very large portion of the earth's surface. It is this wide geographical distribution of their favoured habitat, combined with additional dispersal by ocean currents that make the planktonic Foraminifera such valuable index fossils for world-wide stratigraphic correlation.

The study of planktonic Foraminifera has advanced today to a degree that is often no longer satisfied with a simple description of various species making up a fauna, but requires an examination of the relationship between these species. Many planktonic Foraminifera show rapid and continuous evolutionary changes which can embrace a number of subspecies and even species. An example of this may be found in the *Globorotalia fohsi* group (Bolli 1950) and again in the almost explosive evolution of *Orbulina* in the Lower Miocene (Blow 1956). Similar phylogenetic lineages can be found in many other planktonic Foraminifera throughout the Cretaceous and Tertiary. Although not yet studied in detail, many such trends have been followed tentatively and some were pointed out by the present author (1957a, 1957b, 1957d).

A change in coiling ratio during the life span of some planktonic Foraminifera is another factor that is of use in stratigraphic zonation. It has already been shown in a number of species, or groups of related species, that phylogenetically older forms, as a rule, coil at random, while later there is a distinct preference for either dextral or sinistral coiling (Bolli 1950, 1951b, 1957b, 1957d). Sudden and repeated changes from one direction of coiling to the opposite have been observed in the later evolutionary stages of some species, e. g. in *Globorotalia menardii*. That such rapid changes may find their application in stratigraphic zonation, has been shown by the use of coiling ratios for the correlation of widely spaced cored sections of subrecent sediments collected from the Atlantic (Ericson, Wollin & Wollin 1954; Ericson & Wollin 1956).

Another field in which planktonic Foraminifera are beginning to play a role, is that of paleo temperature determination by means of oxygen isotopic analyses. Because they float in the upper sunlit strata of the oceans, they are much more exposed to climatic changes than bottom dwellers and are thus ideally suited for investigations of this kind. Detailed temperature curves obtained from the oxygen isotope ratio of planktonic Foraminifera, have been reported in particular for the late Tertiary (Emiliani 1955, 1956).

The study of planktonic Foraminifera in Trinidad was initiated by the demand of the oil industry for a detailed interpretation of the complex geology found in the central and southern parts of the island. There, because of their abundance in most sediments, planktonic Foraminifera offered the best method for detailed zonation. Without such fine subdivision, many of the structural complexities, for which Trinidad is well known, would have been difficult to detect and interpret.

A number of papers on planktonic Foraminifera have been published by micropaleontologists of the former Trinidad Leaseholds Ltd., later known as the Trinidad Oil Company and now acquired by the Texas Company under the name of Texaco Trinidad Inc. Through the generosity of the management of the above named Company, it was possible to publish the results. This far-sighted attitude in promoting studies, which eventually proved to be of considerable value to the economic geology of Trinidad, is here gratefully acknowledged.

Dr. H. G. Kugler early anticipated the value of planktonic Foraminifera as index fossils and their use for solving stratigraphic and tectonic problems, not only in Trinidad, but in the Caribbean region as a whole. Our present knowledge of this group in Trinidad has been achieved largely through his continuous encouragement and support.

The present paper has been discussed with Dr. H. G. Kugler and Mr. J. B. Saunders. The writer wishes to thank them both for their helpful comments and suggestions.

REVIEW OF STUDIES ON PLANKTONIC FORAMINIFERA IN TRINIDAD

There are few places outside Trinidad where one finds accumulated in so small an area an almost uninterrupted sequence from the Lower Cretaceous to the Upper Miocene of sediments rich in planktonic Foraminifera. However, it must be mentioned that these favourable conditions are strongly affected by the complexity of Trinidad's geology. Undisturbed surface sections are practically non-existant. This disadvantage was especially felt when it came to phylogenetic studies for which a continuous sequence of sediments is desirable. Fortunately, boreholes which penetrate some of the less disturbed subsurface sections make up to some degree for this lack of good surface profiles.

A first attempt to use planktonic Foraminifera in the zonation of Tertiary sediments was made by CUSHMAN & STAINFORTH in 1945. They subdivided the Oligocene-Miocene Cipero formation into three zones, using *Globigerina concinna* (now *Globigerina ciperoensis*), *Globigerinatella insueta* and *Globorotalia fohsi* as markers. It was not until 1950 that further data on planktonic Foraminifera and their use for biostratigraphic purposes were published. In that year, BRÖNNIMANN (1950a, 1950c) discussed the genus *Hantkenina* and its distribution in the Middle and Upper Eocene. In 1951, the present writer established the distribution of a number of *Globotruncana* species in the Upper Cretaceous of Trinidad. Several of them were already well known as index fossils in the Upper Cretaceous of the Alpine-Mediterranean region, thus making it possible to link American forms with species previously described from Europe.

Short papers dealing with the direction of coiling in a number of planktonic foraminiferal species appeared subsequently (BOLLI 1950, 1951b). Changes in the coiling ratios of certain species during their life ranges were shown to be of use as a tool in stratigraphy. At the same time, morphologic changes, which proved to be of value in the zonation of the upper part of the Cipero formation, were demonstrated within the species *Globorotalia fohsi*. Small keel-less forms (*Globorotalia fohsi barisanensis*) were found to evolve through intermediate stages (*Globorotalia fohsi fohsi*, *Globorotalia fohsi lobata*) to a final robust, keeled form (*Globorotalia fohsi robusta*).

The knowledge of Trinidad's Upper Cretaceous planktonic Foraminifera was advanced by BRÖNNIMANN's publication (1952a) on the Cretaceous Globigerinidae. At about the same time the *Globigerina* species of the Paleocene and Lower Eocene, which had previously only received summary treatment by CUSHMAN & RENZ (1946), were described in detail by BRÖNNIMANN (1952c).

Studies on the origin and evolution of the genus *Orbulina* were carried out by BRÖNNIMANN (1951b) and BLOW (1956). The latter demonstrated the rapid evolutionary development of *Orbulina* from *Globigerinoides bisphaerica*. Although much of BLOW's material came from a section in Falcón, Venezuela, the same lineages were followed by him concurrently in the Cipero and Brasso formations of Trinidad.

In addition to the above listed publications, several others describing planktonic genera or species from Trinidad appeared in the period between 1950 and 1954 (BRÖNNIMANN 1950b, 1951a, 1952b; BRÖNNIMANN & BERMUDEZ 1953; BOLLI 1954).

The next step in the study of Trinidad's planktonic Foraminifera was directed at those forms remaining to be described, in order to establish comprehensive range charts and allow a zonation from the Cretaceous to the Middle Miocene. The publication of papers by BECKMANN (1957), BOLLI (1957a, b, c, d) and BOLLI, LOEBLICH & TAPPAN (1957) largely accomplished this project. BECKMANN discussed the Tertiary Heterohelicidae and their stratigraphic distribution. The present writer described planktonic Foraminifera from the Upper Cretaceous, the Paleocene, the Eocene and the Oligocene-Miocene. In BOLLI, LOEBLICH & TAPPAN's paper on the systematics of planktonic foraminiferal families several new genera and species occurring in Trinidad were introduced.

Some remaining Lower and Upper Cretaceous planktonic species were subsequently published by the writer (1959a). Finally, the present author also described two new planktonic genera, *Leupoldina* and *Grimsdaleinella*, from the Cretaceous (1957e, 1959b). Twenty four papers dealing with planktonic Foraminifera from the Trinidad Cretaceous and Tertiary have thus been published between the years 1950 and 1959.

To date, there has been no description of Trinidad's Upper Miocene to Recent planktonic Foraminifera. Due to unfavourable ecological conditions that have prevailed in Trinidad since the end of the Middle Miocene, they are often totally absent, or only very poorly and sporadically represented, in these younger sediments.

A composite chart has been compiled, showing the distribution of all published planktonic foraminiferal species, subspecies and varieties and in addition, the unpublished Cretaceous Heterohelicidae. This chart listing 236 forms will accompany Dr. H. G. KUGLER's forthcoming treatise on the geology of Trinidad. It gives a good picture of the short stratigraphic ranges of most of the species and subspecies. Forty five foraminiferal zones, essentially based on planktonic Foraminifera, are distinguished from the Lower Cretaceous to the Middle Miocene (see table I). The absence in Trinidad of a number of planktonic index species, such as the Upper Cretaceous *Rotalipora turonica*, *Rotalipora reicheli*, *Globotruncana calcarata*, is indicative of breaks in an otherwise remarkably complete sedimentary sequence.

The following figures illustrate the short stratigraphic ranges of most of the 236 species, subspecies and varieties recognised. Forty six are restricted to one zone, 57 to two, 32 to three, 22 to four, 21 to five, 19 to six and only 39 to seven or more zones.

It is of some interest to give an indication of the average duration in years of a foraminiferal zone as established in Trinidad. If one assumes the time lapse between Barremian and Middle Miocene to be approximately 100 million years and breaks this interval down to 50 zones (in our case 45 established zones and 5 additional ones which would fill existing gaps, especially in the Cretaceous), the duration of one would be 2 million years. This is strictly an average figure which cannot be applied in particular to any one of the established zones. Some of the zones certainly had a longer, others a shorter duration. However, this figure gives an indication of the time required for significant evolutionary changes to take place.

Studies of planktonic Foraminifera are only a part of the wide field of paleontological investigations that have been carried out in recent years in the Cretaceous and Tertiary of Trinidad. A revision of the occurrence and distribution of the benthonic smaller Foraminifera in relation to the zonation based on planktonic Foraminifera has been made. Faunal lists and range charts of these benthonic Foraminifera will be included in Dr. H. G. KUGLER's forthcoming treatise. The wide distribution of some benthonic Foraminifera has recently been emphasized by BARTENSTEIN, BETTENSTAEDT & BOLLI (1957) who described and compared the Trinidad Lower Cretaceous fauna with corresponding faunas from Europe. Many benthonic species of this age with short life spans were found to serve as excellent index fossils for long range correlations.

AGE	EUROPEAN STAGES	GULF COAST	TRINIDAD FORMATION/MEMBER	TRINIDAD ZONES/ZONULES
MIOCENE	HELVETIAN	FLEMING	LENGUA	GLOBOROTALIA MENARDII
	BURDIGALIAN		KARAMAT	" MAYERI — JARVISELLA KARAMATENSIS ZONULE
				" FOHSI ROBUSTA
			HERRERA MEMBER	" FOHSI LOBATA
				" FOHSI FOHSI
				" FOHSI BARISANENSIS
	AQUITANIAN		RETRENCH MEMBER (BRASSO)	GLOBIGERINATELLA INSUETA
				CATAPSYDRAX STAINFORTHI
		ANAHUAC	NARIVA (CIPERO)	" DISSIMILIS — GRAVELLINA NARIVAENSIS ZONULE
OLIGOCENE	CHATTIAN			GLOBOROTALIA KUGLERI
		PAYNES HAMMOCK		GLOBIGERINA CIPEROENSIS CIPEROENSIS
	RUPELIAN	CHICKASAWHAY		GLOBOROTALIA OPIMA OPIMA
	TONGRIAN LATTORFIAN	VICKSBURG		GLOBIGERINA AMPLIAPERTURA
EOCENE UPPER	PRIABONIAN: LUDIAN	JACKSON	SAN FERNANDO MT. MORIAH MB.	GLOBOROTALIA CERRO-AZULENSIS
	PRIABONIAN: LEDIAN		NAVET	GLOBIGERAPSIS SEMIINVOLUTA
EOCENE MIDDLE	LUTETIAN	CLAIBORNE		TRUNCOROTALOIDES ROHRI
				PORTICULASPHAERA MEXICANA
				GLOBOROTALIA LEHNERI
				GLOBIGERAPSIS KUGLERI
				HANTKENINA ARAGONENSIS
				GLOBOROTALIA PALMERAE
EOCENE LOWER	YPRESIAN	WILCOX	POINTE-A-PIERRE / LIZARD UPPER	" ARAGONENSIS
				" FORMOSA FORMOSA
	SPARNACIAN			" REX
PALEOCENE	THANETIAN	MIDWAY	ARENACEOUS / LIZARD SPRINGS LOWER	" VELASCOENSIS
				" PSEUDOMENARDII
	MONTIAN			" PUSILLA PUSILLA
				" UNCINATA
				" TRINIDADENSIS
	DANIAN			RZEHAKINA EPIGONA ZONULE
CRETACEOUS UPPER	MAESTRICHTIAN	NAVARRO	GUAYAGUAYARE	ABATHOMPHALUS MAYAROENSIS
				GLOBOTRUNCANA GANSSERI
				" LAPPARENTI TRICARINATA
	CAMPANIAN	TAYLOR	NAPARIMA HILL	" STUARTI
	SANTONIAN	AUSTIN		" FORNICATA
				" CONCAVATA
	CONIACIAN			" RENZI
	TURONIAN	EAGLE FORD		" INORNATA
	CENOMANIAN	WOODBINE	GAUTIER	ROTALIPORA APPENNINICA APPENNINICA
		WASHITA		GLOBIGERINA WASHITENSIS
CRETACEOUS LOWER	ALBIAN	FREDERICKSBURG		ROTALIPORA TICINENSIS TICINENSIS
		TRINITY	MARIDALE	PRAEGLOBOTRUNCANA ROHRI
	APTIAN			BIGLOBIGERINELLA BARRI
	BARREMIAN	NUEVO LEON	CUCHE	LEUPOLDINA PROTUBERANS
				LENTICULINA OUACHENSIS OUACHENSIS
			TOCO	" BARRI

Table I. Zonation of the Lower Cretaceous – Miocene formations in Trinidad and their tentative correlation with Gulf Coast and European Stages

Advances have been made in the study of other fossil microorganisms. In the field of Ostracoda, VAN DEN BOLD has so far published Paleocene (1957a) and Oligocene-Miocene (1957b, 1958) species. For his distribution charts, he adopted the zonation based on planktonic Foraminifera.

Preliminary investigations on the occurrence and distribution of Tertiary Discoasters and Coccoliths have been carried out by Dr. M. N. BRAMLETTE at the Scripps Institution of Oceanography, La Jolla, California. According to private communication, his first findings are in agreement with the stratigraphic results obtained from planktonic Foraminifera. When better known, these tiny organisms will certainly provide valuable additional aid in inter-regional correlation studies. Because of their minute size and abundance, they are of particular value in cases where only very small amounts of material are available.

Radiolaria will be of similar interest for future systematic and stratigraphic studies. They abound in many of Trinidad's formations between the Lower Cretaceous and the Miocene. Check lists of Tertiary Mollusks are in preparation by Dr. W. P. WOODRING of the United States Geological Survey. It is hoped that it will be possible to tie in Mollusks and larger Foraminifera with the existing foraminiferal zones.

A composite study of all fossil groups will ultimately make the Cretaceous and Tertiary of Trinidad a standard section not only within the Caribbean and the Americas, but also for transatlantic and transpacific correlations.

INTER-REGIONAL CORRELATION

The following is an outline of some correlations obtained primarily in applying Trinidad's planktonic zonation to other regions.

Lower Cretaceous

Recently Lower Cretaceous planktonic Foraminifera have been studied in Trinidad and comparisons made with a number of identical, or very similar forms from other parts of the world (BOLLI 1957e, 1959a; BOLLI, LOEBLICH & TAPPAN 1957). Several species of the Aptian-Albian Maridale formation show close affinities to those from the Duck Creek formation of Texas. *Biglobigerinella barri* is likely to be identical with *Globigerinelloides algeriana* from the Aptian of Algeria. Further, *Schackoina cabri* reported from the Aptian of Tunisia most probably belongs to *Leupoldina*, representatives of which are known to occur in beds of similar age in Trinidad.

Upper Cretaceous

Upper Cretaceous planktonic Foraminifera were the first to be used for inter-regional stratigraphic correlation. Today they are well known and accepted as outstanding index fossils and there is little need to repeat what has been stated in the many publications dealing with their occurrence and distribution. Of the Upper Cretaceous planktonic genera, the species and subspecies of *Globotruncana* and *Rotalipora* are best known. Although long neglected in the Americas, considerable progress has been made in recent years in the study of these genera in Colombia (GANDOLFI 1955), in Texas (SCHWEIGHAUSER 1956) and in Trinidad (BOLLI 1950, 1957a). Representatives of other Upper Cretaceous planktonic genera, such as *Hastigerinoides*, *Praeglobotruncana*, *Rugoglobigerina* and *Abathomphalus*, as well as representatives of the family Heterohelicidae, have proved in recent years to be equally good marker fossils. Combined with *Globotruncana* and *Rotalipora*, they provide a succession of short lived species and subspecies that gives close and accurate stratigraphic control on a world-wide basis.

Paleocene and Eocene

The Paleocene and Eocene of Trinidad are represented by the Lizard Springs, Navet and San Fernando formations. From no other place has a more complete sequence of beds of this time interval been subdivided by planktonic Foraminifera. The short ranges of many species led to the erection of sixteen zones. The writer (1957b), has shown that many of these zones can readily be recognised in sediments of the same age in Barbados, Venezuela, Peru, Mexico and the Gulf Coast of the United States. LOEBLICH & TAPPAN (1957a), gave a comprehensive report on Paleocene and Lower Eocene planktonic Foraminifera from the Gulf and Atlantic coast states. They also discussed their occurrence and distribution on a local and world-wide basis (1957b). An important contribution to the comparison between the stratigraphic ranges of Eocene and Paleocene planktonic and larger Foraminifera has been made by BECKMANN (1958). He confirms an almost identical stratigraphic distribution of planktonic Foraminifera in Cuba as was established earlier in Trinidad. The ranges of twenty genera and species of larger Foraminifera were plotted in relation to the zones established on planktonic Foraminifera.

Paleocene and Eocene planktonic Foraminifera have been little studied in Europe and our knowledge of their occurrence and distribution is, therefore, still rather limited. Papers dealing exclusively, or to a large degree, with planktonic Foraminifera have been published by COLOM (1954) who described many planktonic species from the Eocene of the Alicante area and by BRÖNNIMANN (1952d) and TROELSEN (1957) who gave an account on the planktonic Foraminifera of the Danian of Denmark. Furthermore, HAYNES (1955) mentioned characteristic Upper Paleocene planktonic Foraminifera from the Thanet beds of England.

Numerous other papers contain descriptions or lists of Paleocene and Eocene planktonic Foraminifera but they are, as a rule, not used as index fossils. Many Paleocene and Eocene deposits in the Alpine-Mediterranean region are rich in planktonic Foraminifera and some of them might even be classified as *Globigerina* oozes. The information published so far and the examination by the writer of many samples from North Africa, Turkey, northern Italy, Switzerland and Bavaria confirm that the composition of the planktonic foraminiferal fauna is by and large the same as that found in the Paleocene and Eocene of the Caribbean and the Gulf Coast. It is, therefore, to be expected that before long a close correlation based on planktonic Foraminifera will be established between the Paleocene and Eocene sediments on both sides of the Atlantic.

Oligocene and Miocene

Oligocene and Miocene planktonic Foraminifera have a widespread distribution in the Caribbean region and the zonation established in the Cipero and Lengua formations of Trinidad can often be applied. An outstanding example of this is the study by BLOW (1959) of the planktonic Foraminifera of the Agua Salada group of Falcón, northern Venezuela. Here, planktonic Foraminifera can more easily be followed into younger Miocene beds, whereas in Trinidad the facies of equivalent age was less favourable for this group. BLOW could thus add a *Sphaeroidinella seminulina* zone and a *Globigerina bulloides* zone on top of the *Globorotalia menardii* zone, the youngest that has been established in Trinidad.

Furthermore, he was able to refine the existing zonation by subdividing the *Globorotalia mayeri* zone into a *Globorotalia mayeri/Globorotalia lenguaensis* subzone and a *Globorotalia mayeri/Globigerina nepenthes* subzone, and the *Globigerinatella insueta* zone into a *Globigerinatella insueta/Globigerinoides triloba* subzone and a *Globigerinatella insueta/Globigerinoides bisphaerica* subzone.

Planktonic Foraminifera are also present, though much less dominant, in the Oficina and Carapita formations of Eastern Venezuela, which are time equivalents of the Cipero and Brasso formations of Trinidad. They have been reported by PETERS & SARMIENTO (1956) from the Oligocene and Miocene of the Carmen-Zambrano area of Colombia. Several papers dealing with planktonic Foraminifera in Ecuador (STAINFORTH 1948; CUSHMAN & STAINFORTH 1951; HOFKER 1956) demonstrate that they are useful index fossils in the Oligocene and Miocene as well as in the older Tertiary of this country.

Planktonic Foraminifera are also abundant in the Oligocene and Miocene deposits of many islands in the Greater and Lesser Antilles. In the island of Carriacou in the Grenadines, they have successfully been used in the dating and zoning of Oligocene and Miocene deposits (MARTIN-KAYE 1958). The rich planktonic fauna of the Oligocene upper part of the Oceanic formation of Barbados can readily be correlated with that from the lower part of the Cipero formation of Trinidad. Furthermore, an age equivalence of the younger Bissex Hill formation with the *Globigerinatella insueta* zone of the Cipero formation can be established, while the overlying *Globigerina* marls are of *Globorotalia fohsi* zone s. l. age.

An application of planktonic Foraminifera in biostratigraphic investigations in Central America appeared in WOODRING's publication on the geology of Barro Colorado Island, Canal Zone (1958). For the Caimito formation of Upper Oligocene *Globorotalia kugleri* zone age, he gives lists of planktonic and benthonic smaller Foraminifera, larger Foraminifera, Ostracods, Discoasters, Coccoliths, Gastropods, Pelecypods and Scaphopods. This study of a variety of organisms offers to the student of each branch a valuable tool for comparison of stratigraphic ranges. WOODRING's study is also of interest in regard to the problem of the position of the Oligocene/Miocene boundary in the Caribbean region. In recent years, a number of micropaleontologists have shifted this boundary down from the top of the *Globorotalia fohsi* zone s. l. to at least the top of the *Globorotalia kugleri* zone. Such a position would be in better agreement with that based on the long established molluscan zones.

In the Gulf Coast region, paleontologists generally still favour benthonic Foraminifera in biostratigraphic work, though planktonic Foraminifera often constitute a high percentage of the fauna in Oligocene-Miocene sediments. However, lately there has been increasing interest in the application of planktonic Foraminifera for zonation (Akers 1955; Akers & Drooger 1957).

A first comparison of Tertiary planktonic Foraminifera from the Gulf of Mexico and Caribbean regions with corresponding forms from the Middle East was published by Grimsdale (1951). This was followed by papers on the use of planktonic Foraminifera for a transatlantic correlation of Oligocene and Miocene sediments by Drooger (1956) and Blow (1957). The latter reported several of Trinidad's planktonic zonal markers from Malta and Sicily. In Sicily planktonic Foraminifera were found interbedded with larger Foraminifera, allowing a comparison between the stratigraphic ranges of representatives of these two groups. A similar occurrence of planktonic Foraminifera with larger Foraminifera was recently reported by Hagn (1958) from the Lower Miocene of the Greek Island of Kephallinia.

DATING OF SUBMARINE FOSSIL SEDIMENTS

Microfossils, in particular planktonic Foraminifera, are playing an increasingly important role in the mapping of fossil sediments below the ocean floor. The present writer has had the opportunity to examine numerous core and dredge samples that have been collected from the floors of the Pacific and Atlantic Ocean. A noteworthy feature is the excellent preservation of many of the fossil foraminiferal faunas, ranging in age from Cretaceous to Recent. This may be taken as an indication that fossil sediments which have remained submerged have been subjected to less mechanical stress and diagenetic alteration than have even only slightly disturbed beds of equivalent age above sea level.

An outstanding example of how planktonic Foraminifera may be used in dating fossil submarine outcrops and cores is Hamilton's study (1953) of planktonic Foraminifera collected from mid-Pacific flat topped seamounts (guyots), west of Hawaii. He describes and figures extremely well preserved Upper Cretaceous, Paleocene and Eocene species which aided him in dating the various guyots.

Similarly well preserved fossil planktonic Foraminifera, ranging in age from Eocene to Pleistocene, have been collected in many localities in the Atlantic, (see for example Ericson, Ewing & Heezen 1952). Those examined by the writer were collected in the Hudson submarine canyon which stretches for several hundred kilometers from the continental shelf towards Bermuda, from the Bermuda Rise and also from the Blake Plateau escarpment, which is situated to the east of Florida.

Not all fossil beds which have remained submerged since deposition contain such well preserved faunas. This is shown by a number of dredge samples collected from a Lower Miocene outcrop on the continental shelf in the northwestern Gulf of Mexico (Lankford & Curray 1957). Here, the foraminiferal fauna shows a preservation more typical of equivalent beds of the not too distant Gulf Coast.

Today, geological mapping of the sea floor has hardly been started, but the few examples cited indicate what part planktonic Foraminifera will play in the determination of the age of submarine fossil sediments.

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