TULANE STUDIES IN GEOLOGY

Volume 4, Number 3 June 11, 1966

REGIONAL DISTRIBUTION OF SOME CRETACEOUS ROTALIPORIDAE AND GLOBOTRUNCANIDAE (FORAMINIFERIDA) WITHIN NORTH AMERICA

ROBERT DOUGLAS
DEPARTMENT OF GEOLOGY
UNIVERSITY OF CALIFORNIA, DAVIS
and
WILLIAM V. SLITER[1]
DEPARTMENT OF GEOLOGY
UNIVERSITY OF CALIFORNIA, LOS ANGELES

CONTENTS

I. ABSTRACT

A comparison of Upper Cretaceous planktonic Foraminifera from the Pacific Coast with those of the Atlantic Coast and Gulf-Caribbean regions provides new information on the stratigraphic and paleogeographic distribution of *Praeglobotruncana, Hedbergella, Globotruncana* and *Rugoglobigerina.*

Late Cretaceous planktonic Foraminifera were neither universally nor ubiquitously distributed. Genera ranged widely during the Turonian to early Maestrichtian but some species were restricted geographically.

Many early Upper Cretaceous taxa were cosmopolitan but apparently did not extend into high latitudes. On the West Coast endemism within the Coniacian faunas is marked among the Globotruncanidae and less pronounced in the Rotaliporidae. Cam-

[1] Names arranged alphabetically, no seniority implied.

panian to early Maestrichtian planktonic faunas in North America contain many cosmopolitan globotruncanids.

Late Maestrichtian planktonic index Foraminifera became increasingly restricted to the Tethyan region suggesting a retreat of the tropics. Faunas of this age are not recognized on the Pacific Coast.

Planktonic Foraminifera provide an excellent basis for stratigraphic correlations, between the Pacific Coast and the Gulf-Caribbean region for strata of Cenomanian Turonian and Campanian-early Maestrichtian age.

Thirty-two species of the families Rotaliporidae and Globotruncanidae from California are systematically described and illustrated.

II. Introduction

The Upper Cretaceous planktonic foraminiferal faunas within the northern half of the western hemisphere have been documented from the Pacific Coast, the western interior, the Gulf and Atlantic Coasts of the United States, eastern Mexico and the Caribbean region. These data and the new information from California afford an excellent basis for comparing the stratigraphic and geographic distribution of these microfossils. Such a study, of course, must be based partly on available published information. Some of it is biased in coverage; for example, much of the literature on Cretaceous Foraminifera concerns the late Senonian and Maestrichtian strata and little is published on the Turonian-Coniacian. Few detailed records of the Foraminifera are available from certain regions, such as western Mexico, Central America and parts of the United States, Canada, and Alaska. Despite these shortcomings, enough data are available for a preliminary comparison of the biogeography and biochronology of the three major regions: the eastern Pacific, the Atlantic seaboard, and the Gulf-Caribbean region.

Whenever possible, type material of the taxa herein described has been examined. This material has been kindly loaned by Dr. Richard Cifelli, U. S. National Museum; Mrs. Katherine V. W. Palmer, Paleontological Research Institution, Ithaca, New York; Department of Mineral Sciences, Stanford University and the Department of Geology, University of California, Los Angeles. The writers also wish to expresss their appreciation for topotypic samples provided by Dr. R. K. Olsson from the Mt. Laurel, Mt. Laurel-Navesink, Navesink, and Marshalltown formations; Drs. Alfred R. Loeblich, Jr. and Helen Tappan Loeblich for material from the Eagle Ford (Britton Shale), Austin (Austin and Burditt Members), Taylor (Lower, Pecan Gap, and Upper members) and Navarro (Corsicana and Kemp clays) groups of Texas; and to Dr. E. A. Pessagno, Jr. for material from the Mendez Shale and San Felipe Formation of Mexico and South Bosque Formation of Texas. Samples from California and Baja California, Mexico, were collected by the writers. Special thanks are extended to Dr. Helen Tappan Loeblich for valuable discussions of certain taxonomic aspects of the paper and for critically reviewing it, and to Drs. E. A. Pessagno, Jr. and James W. Valentine, Department of Geology, University of California, Davis for reading parts of the manuscript.

Basic research for this study was generously supported by the American Chemical Society, Petroleum Research Fund, Grant PRF 979-A2 to Dr. H. T. Loeblich. Drawings were made by Mrs. Martha J. Matthews, scientific illustrator, Department of Geology, University of California, Los Angeles.

III. Discussion

Planktonic Foraminifera provide a useful stratigraphic tool for both local and regional correlation, which has been used increasingly over the past decade. Because pelagic microfossils are widely distributed and many taxa appear to be short lived, they approach the ideal as an index fossil. Early workers were mainly interested in the correlative aspects of these fossils and considered their distributions to be world-wide, without ecologic restrictions. However, studies of modern zoöplankton clearly indicate that most have well-defined distributional patterns. They are neither cosmopolitan nor ubiquitous but frequently show considerable "patchiness". Many of these zoöplankton patterns can be closely correlated with specific semi-permanent bodies of oceanic water, or water masses, that are characterized by recognizable physical and/or organic properties (Bradshaw, 1959; Fager and McGowan, 1963).

It has long been recognized that planktonic Foraminifera are latitudinally zoned (Murray, 1897). Recently, work by Phleger, *et al.* (1953), Bé (1959), Bradshaw (1959), Parker (1960), Ericson, *et al.* (1961), and others, has shown that planktonic Foraminifera in the open ocean are latitudinally arranged in bands which reflect general climatic conditions. The bands, however, are not symmetrical but are disrupted by current patterns, particularly major current systems as the Japanese-California currents or the Gulf Stream. North-flowing warm currents carry tropical species north of their usual latitudes, and south-flowing cool waters bring northern forms into southern areas. Along the California coast the transitional fauna of Bradshaw (1959) extends south to near the tip of Baja California (latitude 25° North) but the southern boundary is at 40° latitude in the central Pacific. For this reason, at certain parallels of latitude, planktonic Foraminifera may show a longitudinal "banding". From east to west along the 34th parallel in the Pacific, the transitional fauna is replaced by the central Pacific fauna and that replaced by the northern extension of the equatorial west central fauna off the Japanese Islands (Bradshaw, 1959).

The well developed usual latitudinal banding of the planktonic Foraminifera in the Pacific (as elsewhere) probably is largely due to the thermal gradient between the poles and equator (Eckman, 1953; Fischer, 1960). Today, the maximum variation of marine temperature with latitude is about 30°C but it was apparently much less in the Upper Cretaceous. Recent oxygen-isotope studies indicate Cretaceous paleotemperatures of 14°C for the present Arctic region (Emiliani, 1961). According to Bowen (1961b) temperatures in northern Europe (Poland) ranged from a low of 17°C for the Cenomanian to 21°C for the early Senonian (Coniacian-Santonian). If these figures are representative, they suggest a thermal gradient for the Late Cretaceous about half that at present. Such data support the previous observations of broadly distributed faunal patterns in the Late Mesozoic.

The biogeographic realms or provinces distinguished for the Cretaceous, are, with slight modification, taken from the classic works of Uhlig (1911), Arkell (1956) and others. Arkell (1956) recognized three realms for the Jurassic but generally only two have been adopted by Cretaceous workers; the circum-equatorial Tethyan and the northern Boreal province.

Palmer (1928) showed that rudistids occupied the approximate geographic limits of the Cretaceous Tethys. In North America this sea covered the present Caribbean area and Central America, the northern boundary passing through Mexico, southern Texas and Florida. This is also the area of thick carbonate accumulations, corals, larger Foraminifera and other Upper Cretaceous fossils suggestive of the present tropical environment. Thus, the molluscan faunas, and by association, the planktonic Foraminifera, of the Mexican-Caribbean region are characterized as Tethyan or tropical in aspect (Hamilton, 1953, 1956). The northern Gulf-Atlantic coastal area was not included within the rudistid belt of Palmer (1928). However, their foraminiferal assemblages are very similar to Tethyan faunas during most of the Late Cretaceous. For example, essentially all planktonic species of the Campanian-Maestrichtian strata in New Jersey and Delaware (Olsson, 1960; 1964) are present in Mexico (Olvera, 1959; Pessagno, 1966, in press). The planktonic groups examined for this paper (Rotaliporidae and Globotruncanidae) show no marked faunal boundary between the Gulf-Atlantic and the Tethyan belt. Possibly a critical review of the entire planktonic fauna might alter this observation. Similarities with southern taxa plus the diversity of the planktonic foraminiferal fauna suggest that the Gulf-Atlantic region was subtropical, if not within the tropics.

The rudistids and other molluscan fossils on the West Coast have little resemblance to those of the Tethyan area. Although notable exceptions occur, many of the megafossils of the Late Cretaceous are either Indopacific in distribution, or endemic to the eastern Pacific (*e.g.* the rudist genus *Coralliochama* Matsumoto, 1960; Sohl, 1964; Jones, 1963). The megafaunas as a whole have an asiatic affinity (Matsumoto, 1960). The planktonic Foraminifera from north-western Mexico, California, and Vancouver Island are closer to faunas of the Gulf-Caribbean region than are the contemporaneous molluscan assemblages. There are exceptions in parts of the Upper Cretaceous, however, for at times, the pelagic Foraminifera of the two regions were quite unlike.

In a broad comparison of the fossil zoöplankton on the two sides of North America, several points are apparent. A relatively small proportion of planktonic microfossils, excepting radiolarians, are present in material from California and northwestern Mexico. For example, of some 1000 samples examined from northern California, about 25% contained pelagic species and these formed but a small fraction of the total foraminiferal number. Although there are exceptions, the west coast strata are generally characterized by a paucity of numbers. The heterohelicid-rugoglobigerine marls of Central and eastern America present a sharp contrast to faunas of the eastern Pacific.

In modern oceans a faunal diversity gradient exists between the tropics and the arctic. The lower latitudes contain more genera and species than do the higher latitudes (Eckman, 1953; Fischer, 1960). In the present Pacific, nine genera and 24 species of planktonic Foraminifera occur in the Recent equatorial west central fauna (Bradshaw, 1959) and 3 genera and six species in the subarctic fauna. Data are much less precise for the Upper Cretaceous but a similar pattern of faunal diversity can be established. In the late Campanian approximately ten genera and 25 species occurred in the Tethyan region (Brönnimann, 1952; Gandolfi, 1955; Bolli, 1951, 1957; Fisher and Pessagno, 1965), whereas north of 50° latitude only five genera and six species have been reported (Bergquist, 1961; McGugan, 1964). A comparison of the numbers of genera and species in Texas (Cushman, 1946; Pessagno, 1966, in press) to those in California reveals a close correlation in number of genera, but consistently fewer species in California during the Cenomanian to Campanian. In the Maestrichtian the number of taxa on the West Coast decreases notably and the diversity of Tethyan pelagic Foraminifera increases slightly.

The abundance of radiolarian remains also characterizes rocks bordering the Pacific basin, in both the Mesozoic and Cenozoic. In the Gulf Coast radiolarians are not a conspicuous part of the fossil record, although they are present in Trinidad and Puerto Rico. As radiolarians are essentially open-ocean pelagic organisms (Campbell, 1954), the scarcity of associated planktonic Foraminifera in California is somewhat incongruous and many represent preferential preservation.

The marked distributional restriction of modern planktonic Foraminifera may be atypical for the geologic record (Jenkins, 1965), but the significance of limited or restricted faunal distributions in the past cannot be overlooked. It is not possible to correlate between present high and low latitudes by the Recent planktonic Foraminifera. Similarly the latitudinal banding and faunal diversity gradients of Upper Cretaceous zoöplankton affect the age dating and stratigraphic correlations based on these microfossils. Obviously, it is important to recognize and attempt to understand such distributions. Some of the problems of irregular distributions and stratigraphic correlation have recently been reviewed in an excellent article by Parker (1965). In addition to the latitudinal differentiation of faunas, she notes six other situations present in modern oceans that prevent accurate correlations based on planktonic species. Briefly, these are:

1. Marginal faunas. The faunas of the continental shelf and slope commonly do not represent the total pelagic assemblage due to depth stratification of living species, current action or the increased frequency of common forms under adverse conditions.

2. Small seas. Planktonic species distribution in small seas is irregular and difficult to explain.

3. Instantaneous extinctions. Planktonic species do not always show simultaneous extinctions everywhere as is shown by species that are "extinct" in the Atlantic and still living in the Pacific Ocean.

4. Localized evolution. Endemic species of Recent pelagic Foraminifera suggest that localized evolution is occurring today and probably did in the past.

5. Solution of Calcium carbonate. The tests of planktonic species may be destroyed by solution of calcium carbonate on the sea floor. This destruction may more strongly affect pelagic tests than benthonic ones.

6. Coiling directions. Time horizons based on changes in coiling directions may not be dependable, even for short range correlation.

The present study is based on a few Rotaliporidae and a larger number of Globotruncanidae from the eastern Pacific, Gulf and Atlantic coasts, and the Caribbean. Attention is focused on the distribution of these microfossils in time and space, thereby allowing a better appreciation of their value as age indicators and use in correlation. The writers have had two objects in the present study:

1) to document the Upper Cretaceous planktonic species in California and northwestern Mexico, and

2) to consider the regional paleobiogeographic and stratigraphic distribution of these microfaunas.

The faunal analysis is on a broad scale, largely ignoring the depositional history of the several regions. A meaningful consideration of the conditions and types of sedimentation which occurred in various parts of the Americas during the Late Cretaceous is outside the scope of this paper, but obviously such factors affect both the production and preservation of planktonic and benthonic organisms.

A. Paleogeographic Distribution

Most genera of Upper Cretaceous planktonic Foraminifera have a wide geographic distribution in North America. Of the twenty-five genera recognized in the Treatise on Invertebrate Paleontology, Part C, (Loeblich and Tappan, 1964) only two can be shown to have ranged less than 25 degrees of latitude (in the northern hemisphere) and most extended at least to 40° latitude. North of this parallel data are sparse, but *Globotruncana, Globigerinelloides* and *Planoglobulina* are reported from southern Alaska (Bergquist, 1961), and *Hedbergella* and *Heterohelix* occur in the arctic region (71° latitude) (Tappan, 1962). During much of the Upper Cretaceous (Turonian to Campanian) the faunas of the Tethyan and Boreal provinces show little generic difference. Their characteristic differences are at the specific level, largely involving their relative abundance. Three general distributional types can be recognized among the planktonic species.

1. Cosmopolitan species. Present in both the Pacific and Atlantic and ranging from the low latitudes of the Tethys to at least 45° latitude e.g. *Globotruncana arca* (Cushman).

2. Latitudinal or regionally restricted forms. Widespread in the Pacific and/or Atlantic within definite latitudinal bands, e.g. *Globotruncana contusa* (Cushman).

3. Restricted species. Mostly tropical species restricted to Tethyan waters, and not occurring north of about 25°-30° latitude except in the latest Upper Cretaceous, e.g. *Abathomphalus mayaroensis* (Bolli).

The paleogeographic ranges given here are described in terms of the existing geographic configuration. However, since Upper Cretaceous time, the southern part of California and possibly Baja California was displaced by strike-slip movement along the San Andreas Fault (see Fig. 1). This separation has been described as 300 miles or more (Hill and Dibblee, 1953), although other workers give more conservative estimates from 45 to 145 miles (Bailey, *et al.*, 1964) to 175 miles (Crowell, 1962). Possibly such warm water indicators as *Pseudotextularia, Racemiguembelina* and certain single-keeled species of *Globotruncana* in southern California have been displaced northward as a consequence of this movement.

At present no exclusively Boreal planktonic foraminiferal genera have been recognized and only a few species are restricted to this province. This unique lack of restriction is interesting, and unlike the distribution of other pelagic groups such as the ammonites and baculitids. Such megafossils include restricted Cretaceous taxa in the Pacific basin (Matsumoto, 1960; Jones, 1963). Why then are no Boreal plantkonic foraminiferal genera and only a few species known? Only part of the explanation can be attributed to the small number of studies of Cretaceous microfossils north of 40° latitude, as those studies that have been made indicate a marked scarcity of planktonics. A more probable explanation suggested by the present data is that planktonic Foraminifera were largely restricted to warm or tropical waters in the Late Mesozoic. The few planktonic inhabitants of high latitudes in the Upper Cretaceous were eurythermal cosmopolitans. Thus, northern regions may be characterized by the absence of warm water species rather than by endemic temperate elements.

A cursory examination of the Heterohelicidae reveals some interesting points. The western interior and Gulf-Caribbean regions had a great diversity of species and individuals of the genus *Heterohelix*. On the West Coast neither large numbers of individuals or taxa are common. Even such wide-

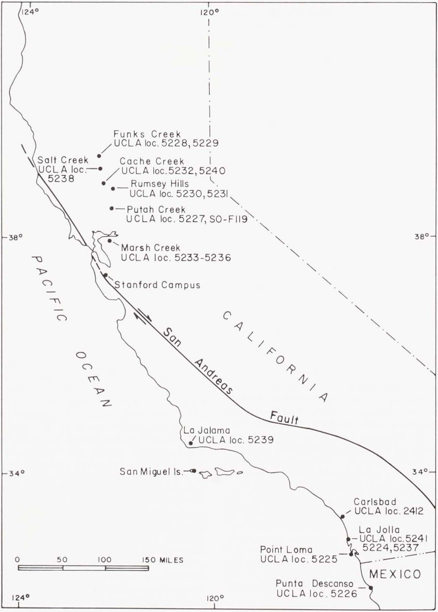


Figure 1. Map of California and Baja California, Mexico, sample localities.

spread species as *H. globulosa* (Ehrenberg) are represented by relatively few individuals as compared to contemporaneous Gulf Coast assemblages. The large robust Late Senonian *Pseudotextularia* and *Racemiguembelina* are rare in the eastern Pacific and probably did not extend as far north as the Sacramento Valley of California. These genera were abundant in the Tethyan region and Gulf-Atlantic region but absent from the western interior. The common *Planoglobulina* of California is the endemic *P. ornatissima* (Cushman and Church). Easily distinguished from Gulf Coast forms by its large size and longer period of biserial development, it is the most characteristic heterohelicid of California Campanian-Lower Maestrichtian rocks. *Planoglobulina austinana* (Cushman) from Vancouver Island (McGugan, 1964) and southern Alaska (Bergquist, 1961) may be conspecific. This genus extended to 60° north latitude in the Pacific and at least to 40° in the Atlantic but is unreported from the western interior.

Based on their distribution and the associated micro- and megafossils, both *Pseudotextularia* and *Racemiguembelina* were mainly tropical in extent in the Upper Cretaceous (particularly the Maestrichtian). The northern limit of their distribution passes through northern Texas and Alabama, and extends northward to New Jersey-Delaware on the Atlantic Coast. Their northern limits on the West Coast is in southern California, some 8 degrees of latitude south of the East Coast occurrences.

The early Upper Cretaceous coiled planktonic foraminiferal genera *Rotalipora, Planomalina, Praeglobotruncana, Hedbergella, Schackoina,* and *Globigerinelloides* were widespread but apparently did not extend into high latitudes. In the western interior, keeled planktonic foraminiferal species have not been reported north of South Dakota (Fox, 1956) and it has been suggested that no planktonic species existed in western Canada and Alaska prior to the Turonian (Eicher, 1966). The genera *Schackoina, Praeglobotruncana* and *Rotalipora* are common in northern California but data are lacking for the Cenomanian deposits of Oregon and southern Alaska. Early Cenomanian Foraminifera have not been well documented on the West Coast although planktonic species of this age are well known in other parts of the Americas. According to Loeblich and Tappan (1961) the Tethyan species *Planomalina buxtorfi* (Gandolfi) occurs in California and Texas but not in the western interior. They also suggest that *Hedbergella washitensis* (Carsey) and *Praeglobotruncana delrioensis* (Plummer) were geographically restricted early Cenomanian species. The former has been reported as far north as Minnesota (Bolin, 1956) and both are common in Texas (Loeblich and Tappan, 1961).

The genus *Rotalipora* is reported from Cuba (Ayala-Castanares, 1962), Mexico and southern Texas (Pessagno, 1966, in press) and Kansas and Nebraska (Morrow, 1934; Loeblich and Tappan, 1961). This distribution probably coincided with deeper and/or more oceanic waters. North of these areas, in Texas (Pessagno, 1966, in press) and Minnesota (Bolin, 1956), and to the west in Colorado (Eicher, 1965), *Rotalipora* is replaced, presumably in shallower waters, by a dominantly *Hedbergella* fauna. Upper Cretaceous keeled planktonic species generally are replaced by *Hedbergella* in higher latitudes (above about 60°) and when passing from oceanic to shallow or coastal deposits. This seems analogous to the distributional relationship between globigerinids and globorotalids in modern oceans. *Globorotalia* is more or less confined to tropical oceanic waters while the more widely distributed species of *Globigerina* predominate in temperate and subarctic regions, and nearer shore (Phleger, 1960).

In the western interior, western Canada and northern Alaska pelagic microfaunas were sparse during the Turonian to Senonian and are characterized by species of *Hedbergella* and *Heterohelix.* The southern boundary of this interior fauna passed through the present states of Colorado, Wyoming, and North Dakota but fluctuated during the Senonian. At infrequent intervals other genera were briefly introduced as far north as Alberta, Canada (Nauss, 1947; Wall and Germundson, 1963). A seaway extended to northern Alaska during the Turonian allowing western interior planktonic species to migrate northward (Tappan, 1964). Cloud (1961) has inferred the current patterns for such a seaway through the Rocky Mountain geosyncline. His analysis is compatible with the introduction of southern species into Alaska but makes the exclusion of keeled globotruncanids from Canada difficult to explain.

The generic composition of the Turonian to Campanian planktonic faunas of California is very similar to those of the Gulf-Caribbean. The early Turonian is characterized by cosmopolitan species, such as *Praeglobotruncana helvetica* (Bolli), *Globotruncana sigali* Reichel, and others (Bolli, 1951, 1957; Brönnimann and Rigassi, 1963; Trujillo, 1960; Pessagno, 1966, in press: see Table 1). None of these species has been identified from the western interior as yet, although their faunal associates *P. stephani* (Gandolfi) and *P. renzi* (Gandolfi) are present (Eicher, 1966). *Praeglobotruncana helvetica* (Bolli) extended into northern California and possibly farther north. According to Bandy (1960), keeled *Globotruncana* occurred in southern Alaska (60° latitude) during the Turonian.

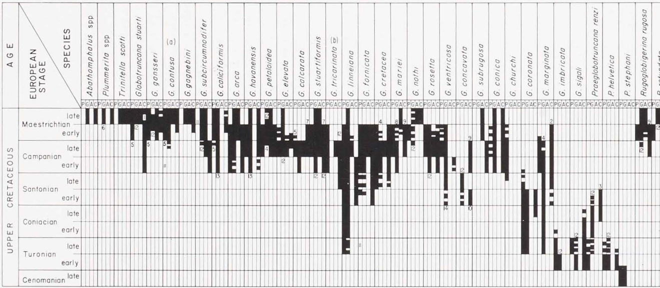
A decrease in pelagic microfaunas at the end of the Cenomanian in California was followed by a steady increase in diversity through the Turonian. Double keeled species such as *Globotruncana coronata* Bolli, *G. imbricata* Mornod, the *G. "linneiana-*type" and several unnamed globotruncanids appeared in the Turonian. One of the latter, *Globotruncana* sp. A of Marianos and Zingula (1966) is present in Texas (Chispa Summit Formation, E. A. Pessagno, Jr., personal communication) but the others appear endemic to the West Coast (Douglas, in preparation). Also during the Middle Turonian *Globotruncana marginata* (Reuss) and other restricted taxa appeared in the Gulf Coast region (Pessagno, 1966, in press). These local species are the first noticeable indication of provinciality between the planktonic foraminiferal assemblages of the eastern Pacific and the Tethyan, although an explanation for their development is not available. The California species may possibly be part of an as yet largely undetected Boreal fauna. Whatever the reason, the restricted nature of the pelagic microfaunas was accentuated in the early Senonian.

During the Conianian and Santonian, the endemism that began in the Turonian became particularly pronounced among the Globotruncanidae, and less well developed in the Rotaliporidae (*Hedbergella*) and Heterohelicidae. Only two *Globotruncana* species are common to the Gulf-Caribbean and Pacific areas during the Coniacian and probably no more than three in the Santonian. Restricted to the western interior, Texas-Mexico and Caribbean regions were: *G. inornata* Bolli, *G. wilsoni* Bolli, *G. angusticarinata* Gandolfi, *G. concavata* (Brotzen), and to a large degree *G. cretacea* (d'Orbigny) and *G. fornicata* Plummer. The two latter species occur locally in late Santonian rocks in California (Funks Formation).

In northern California an increase in the numbers of individuals and species of *Hedbergella* coincided with the development of endemic species of *Globotruncana*. Some of these taxa ranged widely in both time and space, i.e., *H. loetterli* (Nauss), *H. planispira* (Tappan), *H. crassa* (Bolli) and *Clavihedbergella simplex* (Morrow). *Hedbergella loetterli* (Nauss) was originally described from Canada and has been found in northern Alaska (Tappan, 1964). The Caribbean species *H. crassa* (Bolli) was common in California from the Coniacian to the late Senonian. Usually associated with these species are four undescribed species (Marianos and Zingula, 1966).

The Campanian contains many cosmopolitan species of *Globotruncana*. At least 12, and possibly as many as 16 species were common to California, Texas, Arkansas, New Jersey, Delaware, Mexico, Cuba, Trinidad, Puerto Rico and Colombia during the middle and later Campanian (see Tables I and II). Few forms had a restricted or limited distribution. *Globotruncana calcarata* Cushman was a distinctive circum-equatorial late Campanian marker (Bolli, 1951; Sigal, 1952; Brönnimann and Brown, 1956; Edgell, 1957; Herm, 1962; Pessagno, 1962, 1966, in press), throughout the Gulf-Caribbean area, northward to New Jersey and Delaware on the Atlantic Coast (Olsson, 1964). *G. subrugosa Gandolfi* (Gandolfi, 1955; Pessagno, 1962; Olsson, 1964) and *G. subcircumnodifer* Gandolfi (Gandolfi, 1955;=*Rugotruncana tilevi* of Brönnimann and Brown, 1956, see also Berggren, 1962) were other restricted Tethyan species.

Globotruncana churchi Martin is a distinctive and stratigraphically important species in California, that is unreported elsewhere in the Americas, although this apparent restricted distribution may be the result of previous inclusion within *G. arca* (Cushman).



1-*G. stuarti* group of Bolli (1957).

2-*G. lapparenti bulloides* of Bolli (1957).

3-Specific identification in question, see systematic descriptions.

4-Based in part on unpublished data.

5-Hamilton (1953).

6-*Rugoglobigerina hantkeninoides inflata* of Olvera (1959).

7-Fisher and Pessagno (1965).

8-*G. cretacea* of Cushman (1946).

9-Gandolfi (1955).

10-Bolli (1957).

11-Reported by Takayanagi, 1965, but herein referred to another species, see systematic descriptions.

12-Pessagno (1960, 1962, in press)

13-Olvera (1959).

14-Cushman (1946).

(a) *G. contusa* may be synonymous with *G. caliciformis*. The two species are regarded separately here but their stratigraphic distribution based on the literature is probably open to question.

(b) Considerable difference in opinion exists concerning the exact nature of *G. tricarinata*. Its stratigraphic range possibly includes more than one species.

P - Pacific
G - Gulf Coast
A - Atlantic
C - Caribbean

TABLE I
STRATIGRAPHIC DISTRIBUTION OF SELECTED SPECIES OF GLOBOTRUNCANIDAE AND ROTALIPORIDAE IN THE NORTHERN AMERICAS

The sudden reappearance of cosmopolitan species in California and the development of a common Pacific-Gulf-Atlantic globotruncanid fauna following the provinciality of the Coniacian-Santonian might seem to require an unbroken seaway directly linking the Gulf of Mexico with the eastern Pacific. Based on the present distribution of Upper Cretaceous rocks in Mexico, such a portal is unlikely to have existed north of Cuernavaca (Geologic map of Mexico, 1956; Murray, 1961), a position well within the Tethys. Such a dispersal route is therefore unnecessary, as a well-developed Tethyan fauna already existed in the Pacific, both north (Hamilton, 1953) and south of the equator (Edgell, 1957; Belford, 1960). This suggests that the *Globotruncana* species and rugoglobigerines were introduced by a northward spread of warm or tropical waters during the Campanian. Bandy (1960) has suggested that the most characteristic feature of tropical planktonic faunas is the presence of the keeled genera *Globorotalia* and *Globotruncana*. Based on the similarity of these generic types to restricted tropical forms of modern seas, he equated the distributional limit of *Globotruncana* to the boundary of the tropics (20° C isotherm) in the Upper Cretaceous. This appears to over-extend the comparative affinities of *Globotruncana* to modern tropical globorotalids. Although the boundary of the Cretaceous tropics may not be definable by *Globotruncana* alone, the single-keeled species and *Rugoglobigerina*, *Pseudotextularia* and *Pseudoguembelina* were all probably restricted to subtropical or warmer waters. During the Campanian the double-keeled *Globotruncana arca* (Cushman) extended to Alaska (Bergquist, 1961) but there is no record of single keeled species in the Pacific north of California (40° latitude). These taxa strongly suggest that tropical conditions extended latitudinally much higher than in the preceding part of the Senonian. Notably missing from the West Coast however, are the restricted Tethyan species *G. calcarata* Cushman, *G. subcircumnodifer* Gandolfi, and others. Their absence and the small numbers of *Rugoglobigerina rugosa* (Plummer) and most single keeled species of *Globotruncana* are best explained ecologically.

Planktonic foraminiferal genera had very wide geographic ranges in the early Upper Cretaceous. However, in the Maestrichtian a marked change occurred, as several became exclusively low latitude forms. *Abathomphalus* and *Plummerita* were restricted to the Tethys. They occur in Trinidad (Bolli, 1957), Puerto Rico (Pessagno, 1962), Cuba (Brönnimann and Rigassi, 1963), and Mexico (Olvera, 1959) but are missing north of about 25° latitude. *Trinitella* was also characteristic of tropical waters although it ranged northward (Olsson, 1964; Pessagno, 1966, in press). These three genera have not been found in the northern Pacific, nor have *Globotruncana stuarti* (d'Lapparent), *G. gansseri* Bolli, *G. contusa* (Cushman) or *G. gagnebini* Tilev.

The analysis of Cretaceous temperatures based on the oxygen isotope measurements of belemnoids from Europe and Asia (Bowen, 1961a, 1961b, 1961c) do not coincide with the above temperature inferences based on Foraminifera. The interpretation of oxygen isotope data suggest the warmest temperatures in the Coniacian-Santonian, and a general thermal decline through the Campanian-Maestrichtian. Evidence for the southward retreat of the tropics in the Maestrichtian is also suggested by the planktonic Foraminifera. However, the distribution of West Coast Coniacian-Santonian species do not reflect the supposed northward advance of warm temperatures. These planktonic faunas are neither as rich nor as well represented as those of the Campanian, suggesting the reverse of that expected from the isotope-based paleotemperatures. The data here presented suggest cooling in the Pacific in the early Senonian with a northward shift of the tropics in the Campanian.

The absence of the tropical taxa in the California Maestrichtian can be explained stratigraphically, *e.g.* rocks of Late Maestrichtian age are either not present or are unrecognized (see discussion under Stratigraphic Distribution).

The possibility should not be overlooked, however, that the Maestrichtian fossils described from California are younger than generally believed. The megafaunas show a strong provincial or endemic character and are unlike those of the Gulf Coast or Europe (Matsumoto, 1960; Sohl, 1964). Thus Maestrichtian correlations on that basis are imprecise or unsure (Popenoe, *et al.*, 1960). The youngest planktonic foraminiferal assemblage is composed primarily of *Globotruncana havanensis* Voorwijk, *G. petaloidea*

AGE	SPECIES	LONGITUDINAL DISTRIBUTION								LATITUDINAL DISTRIBUTION								
		PACIFIC		GULF			ATLANTIC	CARIBBEAN		10°-20°		20°-30°		30°-40°		40°-50°		
		Central *a*	Eastern margin	Western Interior *b*	Texas *c*	Mexico *d*	*e*	Trinidad *f*	Other	Pacific	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific	Atlantic	
LATE MAEST.	* 1. *Abathomphalus spp.*					■		■			■	///	■					R
	* 2. *Trinitella spp.*				■	■	■	■			■	///	■					R
	* 3. *Plummerita spp.*				X	■		■			■	///	■					R
	* 4. *Globotruncana stuarti*	X			■	■	■	■		X	■	///	■		■			R
CAMPANIAN - EARLY MAESTRICHTIAN	* 5. *G. calcarata*	■			■	■	■		■ 3	■	■	///	■		■			RC
	* 6. *G. gansseri*	■			■	■	■	■	■ 4	■	■	///	■		■			RC†
	* 7. *G. contusa*	■	O		■	■	■	■	■ 3	■		///	■	O	■			RC
	* 8. *G. gagnebini*						■	■			■	///			■			A
	* 9. *G. subcircumnodifer*		O		■	■	■		■ 4/5		■	///	■	O	■			A
	*10. *G. caliciformis*	■			■	■		■		■	■	///	■					R
	11. *G. arca*		■		■	■	■	■		■	■	///	■	■	■	■		C
	12. *G. havanensis*		■		■	■		■	■ 4/6		■	///	■	■				C
	13. *G. petaloidea*		■		■	■	■		■ 5		■	///	■	■	■			C†
	14. *G. elevata*		■		■	■	■		X 4		X	///	■	■	■			
	15. *G. stuartiformis*		■		■	■	■		X 4		X	///	■	■	■			C
	16. *G. tricarinata*		■			X	■				X	///	■	■	■			C†
	17. *G. linneiana*	■	■		■	■	■	■		■	■	///	■	■	■	■		C
	18. *G. fornicata*	■	■		■	■	■	■	■ 4/5	■	■	///	■	■	■			C
	19. *G. cretacea*	■	■		■	■	X			■	■	///	■	■	X			C†
	20. *G. mariei*		■		■ 2		■	X			X	///	■	■	■			RC†
	21. *G. nothi*		■		■	■	■	■			■	///	■	■	■			C
	22. *G. rosetta*	■	■		■	■	■		■ 5	■	■	///	■	■	■			C†
	23. *G. churchi*		■									///		■				P
	24. *G. ventricosa*	■	■		■	■		■		■	■	///	■	■				RC
	*25. *G. subrugosa*					X	■		■ 5		■	///	X		■			A
	26. *G. conica*		■			■		■			■	///	■	■				R†
	27. *Rugoglobigerina rugosa*	■	■		■	■	■	■	■ 4/5	■		///	■	■	■			C
	28. *R. rotundata*		■		■	■	■	■	■ 5	■	■	///	■	■	■	■		C
CONIACIAN SANTONIAN	1. *G. fornicata*				■	///	///	■	■ 5			///	■	■				C
	* 2. *G. concavata*		O		■	///	///	■				///	■	O	■			A
	3. *G. coronata*		■		■	///	///	■			■	///		■				
	4. *G. linneiana*		■	■	■	///	///	■			■	///	■	■	■			C
	5. *G. marginata*			■	■	///	///		■ 5		■	///	■		■			C
	6. *G. cretacea*		X		■	///	///				1	///		■				
TURONIAN	1. *G. linneiana*		■				///					///		■				C
	2. *G. imbricata*		■		■	■	///					///	■	■				
	3. *G. marginata*			■	■		///	■				///			■			
	4. *Praeglobotruncana renzi*		■	X	■	■	///	X			X	///	■	■	X			
	5. *P. helvetica*		■	■	■	■	///	■			■	///	■	■	■	■		C
	6. *P. stephani*		■	■	■	■	///				///	///	■	■	■	■		C

* Not described in this paper.

O Reported in literature but herein referred to another species.

/// Information lacking: time, hiatus, etc.

X Unsure or questionable report.

1- *G. globigerinoides* of Bolli (1957)
2- Banner and Blow (1960)
3- Fisher and Pessagno (1965)
4- Pessagno (1960, 1962)
5- Gandolfi (1955)
6- Voorwijk (1937)

a -Hamilton (1953)
b -Based on: Shaw (1953), Morrow (1934), Loetterle (1937), Bolin (1952), Eicher (1966).
c - Mainly from Cushman (1946), Pessagno, in press.
d - Olvera (1959), Pessagno, in press
e - Jennings (1936), Olsson (1964)
f - Bolli (1951, 1957)
R- Geographically restricted genera or species.
C- Cosmopolitan
RC- Widespread in restricted latitudes or regions
A- Found in Atlantic only.
P- Found in Eastern Pacific only.
†- Indicates assignment tentative.

TABLE II

GEOGRAPHIC DISTRIBUTION OF SELECTED SPECIES OF GLOBOTRUNCANIDAE AND ROTALIPORIDAE IN CENTRAL AND NORTH AMERICA

Gandolfi, *G. arca* (Cushman), *Pseudotextularia* cf. *P. deformis* (Kikoine) and *Racemiguembelina fructicosa* (Egger), and indicates the middle part of the stage.

The low diversity of the fossil zoöplankton on the West Coast in the latest Upper Cretaceous and the absence of Tethyan species suggests a cooling after the "warm" Campanian. This observation supports oxygen-isotope paleotemperature studies that indicate a world-wide retreat of the tropics at this time (Lowenstam and Epstein, 1954; Emiliani, 1961; Bowen, 1961a, 1961b, 1961c). The youngest Maestrichtian pelagic microfauna in California probably represents an eurythermal association, as the taxa occurred both in high latitudes (Olsson, 1960, 1964; Berggren, 1962) and in the Tethys (Bolli, 1957; Gandolfi, 1955). The planktonic Foraminifera traditionally used to identify the Middle and Upper Maestrichtian elsewhere (Bolli, 1957) never entered the West Coast area. They were geographically restricted to the Gulf-Caribbean region and to low latitudes in the eastern Pacific. This apparent stratigraphic problem thus may be largely a paleoecologic or paleobiogeographic one.

Much the same reasoning was given by Olsson (1964) in assigning a Late Maestrichtian age to planktonic species from the mid-Atlantic Coast. Although *Abathomphalus* and *Plummerita* are missing, the presence of *G. stuarti stuarti* (d'Lapparent) indicates a latest Maestrichtian age.

Many areas which may contain Late Upper Cretaceous rocks have not been examined for Foraminifera in the eastern Pacific. Hence it is premature to draw definite conclusions concerning the apparent lack of Upper Maestrichtian faunas. Whatever the cause may have been, it affected wide areas of the northern Pacific as late Upper Cretaceous Globotruncanidae have not been identified in Baja California, California, Vancouver Island, Alaska, or Japan.

B. Stratigraphic Distribution

On Table 1 stratigraphic ranges are compiled for many of the Upper Cretaceous globotruncanids and a few rotaliporids reported from the Americas. The chart both illustrates the general agreement between authors as to the distribution of these Foraminifera in time, and points out several discrepancies. In preparing the data, a certain amount of discrimination was applied in dealing with taxa of confused taxonomic backgrounds. *Globotruncana globigerinoides* Brotzen, for example, and in some cases (where good descriptions exist) *Globigerina cretacea* d'Orbigny have been equated. When types or type material were available to the authors, some specific reassignments have been made, or the original identification queried. These are noted either in the text or plate explanation. Several globotruncanids are not included because they have not been recognized since their original description, or because they are inadequately described and unrecognizable, or because they are systematically invalid. We hope that the end result is a clearer picture of the stratigraphic distribution of these microfossils, but one which has not seriously altered the original information.

1. Cenomanian-Turonian Species

The stratigraphic distribution of early Upper Cretaceous planktonic Foraminifera in different parts of the world has been previously reviewed (Loeblich and Tappan, 1961). Excellent correlation can be made between Upper Cenomanian strata in California, Texas-Mexico, Trinidad, and Puerto Rico based primarily on species of Rotaliporidae, in particular, *Rotalipora greenhornensis* (Morrow), *R. cushmani* (Morrow), *Praeglobotruncana stephani* (Gandolfi), several species of *Hedbergella* and *Schackoina cenomana* (Schacko). The upper part of the so-called "Antelope Shale" and equivalents in California thus correlates with most of the Britton Shale (Eagle Ford Group) of Texas, the lower San Felipe Formation of Mexico and the Robles Formation of Puerto Rico (Pessagno, 1966, in press), and in part with the Pre-Vía Blanca beds of Cuba (Brönnimann and Rigassi, 1963). A few planktonic Foraminifera in the Greenhorn Formation of the western interior suggest correlation with the Upper Cenomanian of the West and Gulf Coasts (Loeblich and Tappan, 1961; Eicher, 1965). However, keeled planktonic species are uncommon or missing, a situation which in general prevails there throughout the Upper Cretaceous. Pelagic foraminiferal faunas from the northern part of the western interior, western Canada, and Alaska are characterized by a high frequency of a few species which have irregular stratigraphic distributions (Wall and Germundson, 1963; Tappan, 1964; Eicher, 1965, 1966). The faunas include species well adapted to life in the shallow seaway of North America or those living at the outer margins of their distribution. Such microfossils possess inherent difficulties for stratigraphic dating and correlation and must be used with caution (Parker, 1965). Some species may be absent for ecologic reasons rather than because the beds were deposited beyond their time range. Also, their first appearance and/or total stratigraphic range may not be equal to the range of these species in lower latitudes.

The genus *Praeglobotruncana* has been described as ranging from the Upper Albian to the Upper Cenomanian (Loeblich and Tappan, 1961, 1964). However, *P. stephani* (Gandolfi) extends into the earliest Turonian in California and Mexico, based on its joint occurrence with *P. helvetica* (Bolli) and *Globotruncana imbricata* Mornod, *G. sigali* Reichel and other globotruncanids. In the western interior it has been reported from strata of both Upper Cenomanian (Loeblich and Tappan, 1961) and Turonian age (Eicher, 1966).

Opinions differ concerning the age of the Eagle Ford Group in the Gulf Coast. Traditionally these strata have been considered Turonian (Stephenson, *et al.*, 1942) but some authors suggest that the upper portion (Britton Shale and Arcadia Park Formation) is late Cenomanian (Loeblich and Tappan, 1961). In a recent study of Gulf Coast planktonic Foraminifera, the upper 10 feet of Britton Shale and the entire Arcadia Park Formation in Dallas County, Texas, are placed in the Turonian (Pessagno, 1966, in press). This age assignment is based on *Globotruncana sigali* Reichel, *G. inornata* (Reuss) *Heterohelix reussi* (Cushman) and several new species locally restricted to Turonian or younger strata.

The Lower Turonian in North America can be defined in terms of pelagic Foraminifera by the first appearance of the genus *Globotruncana* and the last appearance of *Praeglobotruncana*. In California this horizon contains the diagnostic Turonian indices *Inoceramus labiatus* Schlotheim and the ammonite genus *Romaniceras* Spath (Matsumoto, 1960).

In California *Praeglobotruncana helvetica* (Bolli) and *P. renzi* (Gandolfi) occur together near the lower boundary of the Turonian. The latter species is reported from the Coniacian to Santonian in Trinidad (Bolli, 1957), Upper Turonian to Santonian in Texas (Pessagno, 1966, in press) and middle Turonian in the western interior (Eicher, 1966). These differing stratigraphic assignments probably include more than one species (see Systematic Descriptions). The diagnostic species *Praeglobotruncana helvetica* (Bolli), which has a world-wide distribution in the Turonian (Bolli, 1945, 1957; Sigal, 1952; Trujillo, 1960) disappears before the advent of the Coniacian in North America.

The first species of *Globotruncana* are found in Lower Turonian strata and include *G. sigali* Reichel (which is a senior synonym of *G. schneegansi* Sigal), *G. imbricata* Mornod, and *G. marginata* (Reuss). *Globotruncana coronata* Bolli and double keeled, biplanar forms with raised umbilical sutures, here assigned to *G. linneiana* (d'Orbigny), appear somewhat later in the Turonian (Bolli, 1957; Trujillo, 1960; Pessagno, 1966, in press).

In California and the Gulf Coast regions several other species, as yet unnamed or undescribed, are present in rocks of this age (Marianos and Zingula, 1966; Pessagno, 1966, in press).

On the basis of the above Foraminifera, the Lower Turonian can be identified in the Venado Formation, in the lower part of the Marsh Creek Formation (near Locality 556 of Colburn, 1962) and in Member II of the Redding area (Trujillo, 1960) in California, in the Agua Nueva and San Felipe formations of Mexico, the Chispa Summit Formation of Texas (Pessagno, 1966, in press), and possibly in the Carlisle Shale of Colorado (Eicher, 1966) and basal Naparima Hill Formation of Trinidad (Bolli, 1957). The presence of *Praeglobotruncana helvetica* (Bolli) in widely separated limestone and shale deposits in the Franciscan terrain of northern California (Bailey, *et al*, 1964) indicates a Turonian age but does not indicate which part of that stage.

2. Coniacian-Santonian Species

Few stratigraphically diagnostic pelagic Foraminifera were widespread in North America during the early Senonian. In the eastern Pacific region the diverse planktonic assemblage consists largely of endemic species. *Only Globotruncana coronata* Bolli, *G. linneiana* (d'Orbigny), *G. cretacea* (d'Orbigny) and *G. fornicata* Plummer are correlative with the Gulf-Caribbean area. The Coniacian-Santonian Niobrara Formation of the western interior contains *Globotruncana marginata* (Reuss) and *G. canaliculata* (Reuss) (=? *G. linneiana* d'Orbigny) (Bolin, 1952; Shaw, 1953) while correlative strata in western Canada are characterized by "*Hedbergella cretacea* (d'Orbigny)" and *Heterohelix* sp. (Wall and Germundson, 1963). These species are unreported or long ranging on the West Coast.

Coniacian planktonic foraminiferal faunas seem particularly difficult to recognize. Early Senonian assemblages are generally characterized by long ranging forms and best defined by the absence of Turonian species (Cushman, 1946; Bolli, 1951, 1957; Gandolfi, 1955; Trujillo, 1960; Pessagno, 1966, in press, and others). Useful species in Texas and Trinidad are *Globotruncana angusticarinata* Gandolfi, *G. cretacea* (d'Orbigny), *G. inornata* Bolli, *G. coronata* Bolli and the specimens referred to *G. renzi* Gandolfi by Bolli (1957) and Pessagno (1966, in press).

Globotruncana concavata (Brotzen) is a restricted late Coniacian-Santonian marker in the Gulf-Caribbean region (Bolli, 1957; Pessagno, 1962, 1966, in press) but has been reported in older rocks outside of the Americas (Sigal, 1952; Dalbiez, 1955; Barr, 1962; Van Hinte, 1965). A previous California record (Takayanagi, 1965) is based on a misidentification.

Globotruncana fornicata Plummer, a common Senonian form, first appears in the Santonian in the Tethyan region in the Upper Manure Shale of Colombia (Gandolfi, 1955), at the base of the *G. concavata* zone of Trinidad (Bolli, 1957), and in the Austin Chalk and correlatives in the Texas-Mexico area (Cushman, 1946; Pessagno, 1966, in press). A globotruncanid with crescentic spiral chambers similar to *G. fornicata* Plummer is present in the Funks Formation of California. However, typical specimens like those from the Gulf Coast were not present in California prior to the Campanian.

3. Campanian-Maestrichtian Species

In contrast to the earlier Senonian, the Campanian is characterized by sudden diversity of stratigraphically important globotruncanids. This proliferation of species probably reflects, in part the more intensive study of younger Cretaceous strata, and the difficulties in defining the Santonian on the basis of planktonic Foraminifera. This diversity probably began in the late Santonian with the rapid evolution of several double keeled lineages, an increase in single-keeled types, and in the Tethys, an expansion of the rugoglobigerines.

The Lower Campanian of the West Coast contains *Globotruncana arca* (Cushman), *G. fornicata* Plummer, *G. stuartiformis* Dalbiez, *G. ventricosa* White and the last appearance of *G. coronata* Bolli. The early Campanian occurrence (possibly Santonian, Takayanagi, 1965) of *G. arca* (Cushman) versus its restriction to the latest Campanian and Maestrichtian on the Atlantic Coast is more a problem of concept than homeotaxis. The evolution of *G. arca* (Cushman) from *G. tricarinata* (Quereau) was originally suggested by Cita (1948) and its stratigraphic significance amplified by others (Berggren, 1962; Olsson, 1964). In California the Upper Campanian boundary cannot be recognized by this evolutionary change as it has been elsewhere (Olsson, 1964). Specimens indistinguishable from typical *G. arca* (Cushman) are present in lower Taylor strata of the Gulf, and in Campanian rocks of California, Mexico (Pessagno, 1966, in press), and Trinidad (Bolli, 1957). The crux of this problem is the lack of a clear definition of *G. tricarinata* (Quereau), which was originally described from thin-sections. Until the external morphology of this species, and others like it, are adequately described, such problems will persist.

Globotruncana ventricosa White, *G. elevata* (Brotzen), *G. stuartiformis* Dalbiez, *G. mariei* Banner and Blow and *G. rosetta* (Carsey) comprize an important Middle-Upper Campanian assemblage, which allows close correlation both within and without the Americas. *Globotruncana havanensis* Voorwijk, first appears in the high Upper Campanian, is common in the Pacific, Gulf and Caribbean areas but absent from the Atlantic Coast (Olsson, 1964).

G. nothi Brönnimann and Brown and *G. churchi* Martin are restricted to the Campanian-Lower Maestrichtian on the west coast. The distinctive *G. calcarata* Cushman was restricted to the Tethys in the Upper Campanian. It is found in the Taylor Group of Texas (Cushman, 1946; Pessagno, 1966, in press), the Mendez Shale of Mexico (Ayala-Castanares, 1954), Viá Blanca Formation of Cuba (Brönnimann and Rigassi, 1963), Campanian limestones in Panama (Fisher and Pessagno, 1965) and on guyots in the mid-Pacific (Hamilton, 1953) but not in northwestern Mexico, California, Vancouver Island or Alaska.

The evolution of *G. contusa* (Cushman) from *G. fornicata* Plummer occurred in the early Maestrichtian. The high spired, crenulated *G. contusa* (Cushman) is common in the Ripley and Navarro formations of the Gulf Coast and in Maestrichtian rocks of New Jersey-Delaware and the Caribbean. Representatives in California represent the initial step in this evolutionary sequence (Pl. 2, fig. 2), which significantly are found in formations of latest Senonian age. Using these species of *Globotruncana* and certain heterohelicids, the following correlations are suggested:

The Taylor Group of Texas, (Lower Taylor, Pecan Gap, and Upper Taylor formations), the middle Mendez Shale and upper part of the San Felipe Formation of the Tampico area, Mexico, and the upper part of the Naparima Hill and lower Guayaguayare formations of Trinidad correlate with the Forbes, the upper part of the Marsh Creek, upper Marlife and lower Uhalde formations in northern California and with parts of the Rosario Formation in southern California.

The upper part of the Marsh Creek Formation and the upper section at La Jolla (San Diego County), in California are of Maestrichtian age. They appear to be stratigraphic equivalents of the Neylandville Marl, Marlbrook Marl and Saratoga Chalk and perhaps the lower portions of the Corsicana and Arkadelphia Marl of the Gulf Coast, the lower part of the Papagallos Shale of northeastern Mexico, Rio Yauco Formation and upper part of the Parquera Limestone of Puerto Rico and the middle portion of the Guayaguayare Formation of Trinidad.

Reference to Table 1 suggests that most late Campanian species of *Globotruncana* continued into the early Maestrichtian. On the west coast the first appearance of *Rugoglobigerina rugosa* (Plummer) (see Systematic Descriptions), *R. rotundata* Brönnimann and the joint occurrence of *Globotruncana nothi* Brönnimann and Brown, *Globotruncana havenensis* Voorwijk and *G. petaloidea* Gandolfi indicate early Maestrichtian. Generally the rugoglobigerines do not become abundant nor widespread in the Americas until the latest Upper Cretaceous. Reports of *R. rugosa* (Plummer) in the Campanian of the Gulf-Caribbean region (Gandolfi, 1955; Pessagno, 1962, 1966, in press) suggest that it may have evolved in the Tethys and spread northward. It is not found in California or New Jersey (Olsson, 1964) prior to early Maestrichtian.

In the Tethyan region, the Middle and Upper Maestrichtian is defined by *Globotruncana gansseri* Bolli, *G. contusa* (Cushman) and the *Abathomphalus mayaroensis* zone (Bolli, 1957). Also indicative of this age are the species *G. stuarti* (d'Lapparent), *G. gagnebini* Tilev, *Globotruncana havanensis* Voorwijk and the genera *Trinitella* Brönnimann and *Plummerita* Brönnimann. Except for species of *Abathomphalus* and *Plummerita*, which did not extend above 25 degrees north latitude, this fauna and associated heterohelicids allow correlation between the northern Gulf and Atlantic Coastal regions and the Tethyan faunas of Mexico, Cuba, Puerto Rico and Trinidad. However, this entire assemblage is unreported from California, Vancouver Island, or Alaska (Bergquist, 1961; McGugan, 1964). One of several possibilities may explain this anomaly: 1) A stratigraphic hiatus separates the west coast Upper Cretaceous from the Tertiary, 2) Strata of Late Maestrichtian age are present but, a) contain no planktonic Foraminifera, or, b) the Upper Maestrichtian Globotruncanidae of the Gulf and Caribbean area were excluded from the northern Pacific basin.

In California, apparently unbroken stratigraphic sequences can be found through the Late Mesozoic into the Cenozoic, as in the Moreno Formation (Popenoe, *et al.*, 1960; Martin, 1964). Here as elsewhere in the state, the last globotruncanid appears several hundred feet below the Paleocene contact. The sequence contains benthonic Foraminifera and ammonites but they are not indicative of a precise age within the Maestrichtian (Martin, 1964; Matsumoto, 1960; Popenoe, *et al.*, 1960).

Based on planktonic Foraminifera and ammonites, the "D-2 zone" of Goudkoff (1945) is early Maestrichtian in age and the "Cheneyan Stage" or his "A zone" is Danian (Loeblich, 1958). The interim zones should therefore include the late Upper Cretaceous as no apparent hiatus separates these zones in parts of the San Joaquin Valley. Rocks of younger Maestrichtian age thus may be present, but do not contain keeled planktonic foraminiferal species. Adverse ecologic conditions might explain the local exclusion of pelagic organisms but this globotruncanid assemblage is also lacking in Baja California, Mexico, Vancouver Island, Alaska and elsewhere. The youngest planktonic foraminiferal assemblage presently identified in California is characterized by *Globotruncana havanensis* Voorwijk, *G. arca* (Cushman), *Pseudotextularia elegans* (Rzehak), *P.* cf. *P. deformis* (Kikoine) and *Racemiguembelina fructicosa* (Egger). These elements extend into the Upper Maestrichtian in the Gulf-Caribbean area but without other associated taxa do not indicate an unequivocal Late Maestrichtian age.

The California molluscan faunas have strong endemic or Indo-pacific affinities (Popenoe, *et al.,* 1960; Matsumoto, 1960) but provide some useful stratigraphic correlatives. *Baculites lomaensis* Anderson and *B. columna* Morton occur in the Prairie Bluff Chalk of Alabama and the Corsicana and Neylandville marls of Texas, respectively. Both are apparently of Lower or Middle Maestrichtian age (Matsumoto, 1960). The highest beds in the Moreno Formation contain *Baculites rex* Anderson, *Eubaculites ootacodensis* (Stoliczka), *Deplomoceras* sp. and *Neophulloceras hetonaiense* Matsumoto, and should thus be Middle to late Maestrichtian in age (Popenoe, *et al.,* 1960). These strata can be correlated with the Maestrichtian of Japan but do not indicate which part of the stage is represented.

Thus precise correlation between the Middle-Upper Maestrichtian of the West Coast and the Gulf-Caribbean is presently only tentative. More work is required for locating and documenting the latest Upper Cretaceous foraminiferal species of the eastern Pacific areas.

IV. Systematic Descriptions

The classification followed is that of the Treatise of Invertebrate Paleontology, Part C (Loeblich and Tappan), 1964. The fundamental criteria upon which the genera are based and utilized in this paper are:

1. Apertural characteristics, including position and shape.
2. Chamber modifications including the general shape, and the presence of one or more keels, or poreless margin.
3. General shape and development of test.

Specific characters include the following:

a. Size, shape and proportions of test including relative size of umbilicus.
b. Numbers, shape, position and proportions of chambers.
c. Surface ornamentation.

Although it is difficult to assign a greater priority to either a or b, they have much greater consistency than does the remaining character.

Species distinguished largely on degree, intensity, or position of surface ornamentation are difficult to recognize because such features are rarely consistent within a single population. Suites of individuals of the same species commonly exhibit wide latitudes in the development of surface ornamentation. *Globotruncana arca* (Cushman), for example, may be smooth to beaded to nearly rugose on the spiral side of the chambers, and the elevated sutures separating the chambers vary in the same way (see pl. 2). Variation in degree of surface ornamentation within a species of *Hedbergella* or *Rugoglobigerina* may be quite pronounced. The differences are particularly apparent when specimens of a species are compared from different areas. Olsson, (1964), for example, noted that the New Jersey rugoglobigerines have thinner, less flattened spines and a less obvious meridional pattern than their Gulf Coast counterparts. The type of surface ornamentation (*e.g.* spinose or pitted), is a distinguishing feature, however, and is probably of significant value. If the kind of surface ornamentation is controlled by the wall microstructure, and an extension of it, as it is in Cenozoic planktonic Foraminifera (Lipps, 1966, in press), it may be an important taxonomic criterion.

Complete synonymies are not presented herein; only the original reference is given.

Superfamily GLOBIGERINACEA Carpenter, Parker, and Jones, 1862

Family ROTALIPORIDAE Sigal, 1958

Genus HEDBERGELLA Brönnimann and Brown, 1958

HEDBERGELLA PRAEHELVETICA (Trujillo)

Pl. 5, fig. 3

Rugoglobigerina praehelvetica TRUJILLO, 1960, Jour. Paleontology, v. 34, no. 2, p. 340, pl. 49, fig. 6a-c.

Test free, low trochospiral, spiral side nearly flat, axial periphery hemispherical to rounded, equatorial periphery lobate. Chambers 5 to 6 in final whorl, globular, inflated, increasing gradually in size. Sutures curved, depressed on spiral side, straight, radial, depressed on umbilical side. Wall calcareous, perforate throughout, radial in structure, initial chambers of spiral side smooth, later chambers beaded, umbilical side coarsely beaded to rugose. Umbilicus deep and wide. Aperture an interiomarginal, umbilical-extraumbilical arch, with narrow bordering lip.

Greatest diameter of hypotype 0.36 mm, thickness 0.16 mm.

Remarks: This species is similar to and sometimes associated with *Praeglobotruncana helvetica* (Bolli). It may be differentiated by the more globular chambers, absence of a rim on the edge of the spiral chambers and the finely perforate margin.

Types and occurrences: Figured specimen from Venado Formation, Putah Creek, Yolo Co. (UCLA loc. 5227), California.

HEDBERGELLA sp. 1

Pl. 5, fig. 10

Test free, low trochospiral, gently convex on spiral side, umbilical side nearly flat, equatorial periphery lobate, axial periphery ovate to broadly truncate, covered with large spines. Chambers globular, 5 to 6 in final whorl, compressed and subcircular to subrectangular on umbilical side. Sutures radial and depressed, slightly curved on spiral side. Wall calcareous, perforate, radial in structure, surface spiny to rugose, coalesced spines on umbilical side radially arranged. Umbilicus wide and shallow. Aperture an interiomarginal, umbilical arch extending from umbilicus nearly to margin, bordered by apertural lip.

Greatest diameter of figured specimen 0.37 mm, thickness 0.27 mm.

Remarks: The spiny surface ornamentation of this species, with radially arranged umbilical spines, is suggestive of the genus *Rugoglobigerina.* However, none of the specimens examined possess tegilla and the aperture is a single interiomarginal opening which excludes the taxon from the Globotruncanidae. It is tentatively placed in the genus *Hedbergella.*

Types and occurrences: Figured specimen from Sites Formation, Funks Creek, Colusa Co. (UCLA loc. 5228).

Unfigured specimens from unnamed Cretaceous strata near Benicia, Solano Co.; Yolo Formation, Yolo, Co. (UCLA loc. 5240); and, Marsh Creek Formation, Contra Costa Co. (loc. UO 773), California.

HEDBERGELLA sp. 2*

Pl. 1, fig. 1

Test free, low trochospiral, biconvex, spiral side nearly flat, inner whorls somewhat raised, axial periphery ovate, equatorial periphery lobate. Chambers globular, subcircular to subrectangular on spiral side, subtriangular on umbilical side, increasing gradually in size, generally 5 in final whorl. Sutures distinct, depressed, gently curved backward on spiral side, depressed, nearly radial on umbilical side. Wall calcareous, perforate, radial in structure, spiral surface with coalesced spines radiating tangentially from early chambers, umbilical side with heavy pustules or ridges radiating from umbilicus. Umbilicus wide and shallow. Aperture somewhat obscured by matrix material but appears to be interiomarginal, umbilical, with large apertural flap.

Greatest diameter of figured specimen 0.60 mm, thickness 0.26 mm.

Remarks: This species is placed in *Hedbergella* based on its porous margin and apertural features. The surface ornamentation of well preserved specimens are, however, suggestive of *Rugoglobigerina.*

Hedbergella sp. 1 is separated from *H.* sp. 2 by its blunt axial periphery, elevation of the inner whorls on the spiral side and differences in ornamentation.

Type and occurrences: Figured specimen from the lower Sites Formation, Funks Creek, Colusa Co. (UCLA loc. 5228).

Unfigured specimens from Cretaceous strata near Benicia, Solano Co., and Marsh Creek Formation, Contra Costa Co. (loc. UO 773), California.

Genus PRAEGLOBOTRUNCANA Bermúdez, 1952

PRAEGLOBOTRUNCANA HELVETICA (Bolli)

Pl. 5, fig. 1

Globotruncana helvetica BOLLI, 1945, Eclogae Geol. Helv., v. 37 (1944), no. 2, p. 226, pl. 9, figs. 6-8, text-fig. 1 (9-12).

Test free, low trochospiral, spiral side nearly flat, inner whorls slightly raised, axial periphery hemispherical with beaded rim on edge of spiral side, equatorial periphery lobate. Chambers globular, subcircular to petaloid on spiral side, strongly inflated on umbilical side, increasing gradually in

* This species is described as a new taxon by Marianos and Zingula, 1966 (in press).

size, 5 or 6 in final whorl. Sutures curved and depressed on spiral side, straight, radial and depressed on umbilical side. Umbilicus wide and deep. Aperture interiomarginal, umbilical, tegilla not present on examined specimens.

Greatest diameter of hypotypes 0.34-0.39 mm, thickness 0.17-0.26 mm.

Remarks: This species is placed in the genus *Praeglobotruncana* because it has a simple aperture without tegilla or accessory apertures. The described hypotype (pl. 2, fig. 1), closely resembles specimens from Trinidad (Bolli, 1957, pl. 13, figs. 1a-c). Individuals which are thicker and have more elevated rims on the spiral side probably represent the more common type.

The species is present in the Caribbean (Bolli, 1957), Texas-Mexico region (Pessagno, 1966, in press) and California (Trujillo, 1960; Bailey, *et al.*, 1964) but is not recorded from the western interior of the United States.

Types and occurrences: Figured hypotype from lower Venado Formation, Putah Creek, Yolo Co. (UCLA loc. 5227), California.

Unfigured hypotypes from Marsh Creek, Contra Costa Co. (UCLA loc. 5233); unnamed Cretaceous strata, west end of San Miguel Island, Santa Barbara Co.

Unfigured hypotypes also recorded by Trujillo (1960) from Member II, Redding area, Shasta Co., and Bailey, *et al.* (1964) from the Franciscan limestones north of San Francisco, California.

PRAEGLOBOTRUNCANA RENZI (Gandolfi)
Pl. 4, fig. 3

Globotruncana renzi GANDOLFI, 1942, Riv. Ital. Pal., v. 48, Supp. mem. 4, p. 124, pl. 3, fig. 1; pl. 4, figs. 15, 16, 28, 29; pl. 10, fig. 2; text-fig. 45.

Test free, low trochospiral, biconvex, equatorial periphery subcircular, slightly lobate, axial periphery angular truncate in early portion, later angular rhomboid with two narrowly spaced keels which commonly merge. Chambers increase gradually in size, 5 or 6 in final whorl, subcircular, subcrescentic on spiral side, subrectangular on umbilical side, overlapping. Sutures on spiral side curved and beaded, umbilical sutures depressed, nearly radial. Wall calcareous, perforate, radial in structure, surface lightly rugose, smooth in later chambers, keels may have blunt spines. Umbilicus narrow and shallow. Aperture interiomarginal, umbilical arch extending from umbilicus half way to margin.

Greatest diameter of hypotype 0.51 mm, thickness 0.27 mm.

Remarks: The species is placed in the genus *Praeglobotruncana* because it has a single interiomarginal aperture, and lacks tegilla, and accessory apertures.

Considerable taxonomic confusion surrounds this species. The name *Globotruncana renzi* was applied by Thalman (1942) and Gandolfi (1942) to specimens described by O. Renz but the former designation is invalid (see Ellis and Messina, Suppl. 1958, no. 2, under *G. renzi* Thalmann). However, some later workers have not followed this interpretation. Eicher (1966), after Klaus (1960), suggests that *G. renzi* Thalmann is the valid name, that the species be placed in *Praeglobotruncana* and that *Globotruncana renzi* Gandolfi is a different species. Bolli (1945, 1957), Pessagno (1966, in press) and others, have based their identifications on the description and figures of Gandolfi (1942). Also, Pessagno (1966, in press) indicates that the syntypes of Gandolfi included more than one species and restricts his usage to specimens examplified by pl. 4, fig. 15, and text-fig. 45 of Gandolfi (1942). As noted by Trujillo (1960), the undulating surface and depressed sutures of the spiral side of *G. renzi* Gandolfi of Bolli (1957) are unlike the type illustrations. The stratigraphic range in Trinidad also appears to be younger than occurrences in Europe (Sigal, 1952; Hagn and Zeil, 1954; Klaus, 1960) or the West Coast (Trujillo, 1960).

The specimens here referred to *Praeglobotruncana renzi* are based on Gandolfi (1942). They are identical to previously described California examples (Trujillo, 1960) but differ from those of Eicher (1966) or Pessagno (1966, in press).

A complete understanding of the stratigraphic and geographic distribution of "*Globotruncana renzi*" must await a clearer taxonomic definition of the taxon.

Types and occurrences: Figured hypotype from lower Venado Formation, Putah Creek, Yolo Co. (UCLA loc. 5227).

Unfigured hypotypes from Marsh Creek, Contra Costa Co. (UCLA loc. 5233), and Venado Formation, Stone Corral Creek, Colusa Co.

The stratigraphic range appears to be questionably late Cenomanian to upper Turonian in California.

PRAEGLOBOTRUNCANA STEPHANI
(Gandolfi)
Pl. 4, fig. 1

Globotruncana stephani GANDOLFI, 1942, Riv. Ital. Pal., v. 48, Suppl. Mem. 4, p. 130, pl. 3, figs. 4-5; pl. 4, figs. 36, 37, 41-45; pl. 6, fig. 4, 6; pl. 9, figs. 5, 8; pl. 13, fig. 5; pl. 14, fig. 2.

Test free, trochospiral, moderately to strongly spiroconvex, axial periphery ovate with distinct carinal band, equatorial periphery lobate. Chambers subrounded, later ones slightly depressed on spiral side, becoming subangular, commonly 5 or 6 in final whorl. Sutures distinct, gently curved and depressed on spiral side, nearly radial on umbilical side. Wall calcareous, perforate, radial in structure, surface finely spinose, carinal band rugose. Umbilicus narrow and shallow. Aperture an interiomarginal, umbilical arch, commonly with large broad flap. Apertural area may be surrounded by a smooth oval area.

Greatest diameter of hypotype 0.31, thickness 0.17 mm.

Remarks: In a recent revision of Cenomanian planktonic foraminifera, Loeblich and Tappan (1961) noted the wide geographic range of this species in North America and elsewhere. Its apparent absence from Trinidad has been explained by a stratigraphic hiatus (Bolli, 1957).

The association of this species with true globotruncanids, such as *Globotruncana sigali* Reichel and *G. imbricata* Mornod, suggests that it extends into the lower Turonian on the Pacific Coast.

Types and occurrences: Figured hypotype from Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5233).

Wide spread in the Cenomanian, it is known from the Greenhorn Formation, Kansas, Eagle Ford Group (Britton Shale), Texas and from several localities in Europe (Loeblich and Tappan, 1961). It is also reported from the Cenomanian of Clark Valley, Glenn Co., Calif. (Loeblich and Tappan, 1961).

Family GLOBOTRUNCANIDAE Brotzen, 1942
Genus GLOBOTRUNCANA Cushman, 1927
GLOBOTRUNCANA ARCA (Cushman)
Pl. 2, figs. 6, 7

Pulvinulina arca CUSHMAN, 1926, Cushman Lab. Foram. Res. Contr., v. 2, pt. 1, p. 23, pl. 3, figs. 1a-c.

Test free, low to moderately high trochospiral, biconvex, usually more spiroconvex, equatorial periphery lobate, axial periphery angular truncate with two distinct keels. Chambers, 6 or 7 in final whorl, increasing gradually in size, petaloid to crescentic on spiral side, subrectangular on umbilical side, imbricated. Sutures curved, limbate, beaded on spiral side, slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface of early chambers lightly pustulose, later ones smooth. Umbilicus deep and wide. Primary aperture interiomarginal, umbilical, commonly covered by tegilla with intra- and infralaminal apertures.

Greatest diameter of hypotypes 0.41-0.49 mm, thickness 0.14-0.24 mm.

Remarks: Globotruncana arca (Cushman) appears to be truly cosmopolitan. The same morphologic types is well represented on the West Coast, Gulf and East Coasts of North America, and in the Caribbean area. The form is biconvex-spiroconvex with a distinct carinal band sloping toward the umbilicus. Specimens examined from the Pacific and Gulf Cretaceous vary in degree of biconvexity, and surface ornamentation. Berggren (1962) believes *G. arca* (Cushman) to be an endpoint of the *lapparenti-tricarinata-arca* sequence and regards the species as restricted to the Maestrichtian. Although this evolutionary development seems plausible, *G. arca* (Cushman) first appears, outside of Scandinavia, in late Santonian to early Campanian times. This species differs from *G. tricarinata* (Quereau) in the more convex spiral side, and oblique carinal band, and in lacking the periumbilical extension of the umbilical carinae which resembles a third keel.

Types and occurrences: Figured hypotypes from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241); Marsh Creek Formation, Contra Costa, Co. (UCLA loc. 5236).

Unfigured hypotypes examined from the Panoche Formation, Moreno Gulch, Fresno Co. (Martin, 1965); Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5230 and 5231); Cretaceous strata, Carlsbad, San Diego Co. (UCLA loc. 2412).

Unfigured hypotypes from the Upper Taylor Group, Onion Creek, Travis Co., Texas (Plummer loc. 226-T-8); Mt. Laurel-Navesink Formation, New Jersey (Olsson, 1964).

This species has also been reported from British Columbia, Canada (McGugan, 1964), Trinidad, West Indies (Bolli, 1951, 1957), and Colombia, South America (Gandolfi, 1955).

Stratigraphically this species appears to range from the late Santonian to Maestrichtian.

GLOBOTRUNCANA CACHENSIS n. sp.
Douglas
Pl. 5, fig. 5

Globotruncana sp. *C* MARIANOS AND ZINGULA, 1966, Jour. Paleontology, v. 40, in press.

Test free, low to high trochospiral, spiroconvex, axial periphery ovate, marginal band with well developed keel on spiral edge in early chambers, later rounded, equatorial periphery lobate. Chambers globular, increasing gradually in size, 5 to 6 in final whorl. Sutures curved, limbate, beaded on early chambers of spiral side, later ones slightly depressed, umbilical sutures depressed, nearly straight, radial. Wall calcareous, radial in structure, perforate, surface rugose, particularly the carinal band, later chambers usually smooth. Umbilicus deep and wide. Aperture interiomarginal, umbilical. Specimens examined are without preserved tegilla.

Greatest diameter of holotype 0.43 mm, thickness 0.24 mm.

Remarks: Juvenile forms are similar to *Praeglobotruncana helvetica* (Bolli) but are readily distinguished from the latter by the spiroconvexity and ovate chambers in final whorl, which lose the distinct keel on the spiral edge of the margin. Axial thin-sections show a wide poreless margin in the early chambers which becomes narrower with age. Margins of the final chamber may be entirely porous.

The stratigraphic range is from Middle Turonian to Coniacian.

Types and occurrences: Figured holotype and unfigured paratypes from the Yolo Formation, Salt Creek, Colusa Co. (UCLA loc. 5238), California. All specimens on deposit at the Department of Geology, University of California, Los Angeles.

Unfigured specimens from the Yolo Formation, Cache Creek, Yolo Co. (UCLA loc. 5240); unnamed Cretaceous strata near Martinez, California. Also recorded from the Dry Creek area, California (Marianos and Zingula, 1966, in press).

GLOBOTRUNCANA CHURCHI Martin
Pl. 2, fig. 10; Pl. 5, fig. 2

Globotruncana churchi MARTIN, 1964, Jb. Geol. Bundesanst. Sonderband 9, p. 79, pl. 9, figs. 5a-c.

Test free, trochospiral, biconvex, spiral side moderately trochospiral with inner whorls distinctly elevated, umbilical side often slightly concave, axial periphery truncate, inclined towards umbilicus, with two distinct keels, umbilical keel often weakly developed on last chamber, equatorial periphery moderately lobate. Chambers 6 to 7 in final whorl, slightly inflated, increasing gradually in size, petaloid on spiral side, subrectangular on umbilical side. Sutures curved, limbate, elevated, beaded on spiral side, slightly curved, depressed on umbilical side. Wall calcareous, perforate, surface initially pustulose, later chambers smooth. Umbilicus moderately wide, deep. Aperture interiomarginal, umbilical, covered by tegilla with infra- and intralaminal accessory apertures.

Greatest diameter of hypotypes 0.31-0.41 mm; thickness 0.19-0.26 mm.

Remarks: This species was first recorded from Campanian strata near Coalinga, California (Cushman and Church, 1929) but was referred then and by most successive authors to *G. arca* (Cushman). Martin (1964) recognized its unique morphologic features and erected the species *G. churchi.* We concur in the recognition of this diagnostic and stratigraphically useful species. It is found in strata of Santonian to Campanian age in several California localities. *Globotruncana churchi* Martin is separated from *G. arca* (Cushman) by the elevated inner whorls on the spiral side and the smaller, more petaloid chambers.

Types and occurrences: Figured hypotypes from unnamed Cretaceous, Carlsbad, San Diego Co. (UCLA loc. 2412); Sites Formation, Colusa Co.

Unfigured hypotypes from Cretaceous strata, Stanford University Campus, Stanford, Santa Clara Co.; from the Forbes Formation, Putah Creek, Yolo Co.; Marsh Creek Formation, Contra Costa Co.

GLOBOTRUNCANA CONICA White
Pl. 3, fig. 9

Globotruncana conica WHITE, 1928, Jour. Paleontology, v. 2, p. 285, pl. 38, fig. 7 a-c.

Test free, trochospiral, biconvex, umbilical side slightly convex to flat, axial periphery acute, with a distinct single keel, equatorial periphery slightly lobate. Chambers 6 to 7 in final whorl, increasing gradually in size, petaloid on spiral side, subpetaloid on umbilical side. Sutures curved, elevated, limbate, beaded on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth to finely hispid. Umbilicus moderately large, deep. Aperture interiomarginal, umbilical, covered by tegilla with accessory apertures.

Greatest diameter of hypotype 0.49 mm; thickness 0.28 mm.

Remarks: Specimens referred to this species have been reported from Mexico (White, 1928; Ayala, 1954; Olvera, 1959), Trinidad (Cushman and Renz, 1947), and Texas (Pessagno, 1966, in press). Pacific Coast forms are restricted to southern California and occur only sporadically. The species is distinguished by the conical spiral side, nearly flat umbilical side and distinct single keel. *Globotruncana conica* White differs from high spired specimens of *G. fornicata* Plummer in possessing petaloid rather than broadly crescentic chambers and in lacking the double keel of the latter species.

Types and occurrences: Figured hypotype from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5223).

GLOBOTRUNCANA CORONATA Bolli

Pl. 4, fig. 4; Pl. 5, figs. 7, 8

Globotruncana lapparenti coronata BOLLI, 1945, Eclogae Geol. Helv., v. 37 (1944), p. 233, fig. 1, abb. 21, 22; pl. IX, figs. 14, 15.

Test free, large, biconvex, low to medium trochospiral, axial periphery angular truncate becoming rhomboid truncate in later chambers, with two distinct, closely spaced keels which may coalesce or merge on the penultimate chamber. Chambers flat to somewhat inflated, subcircular on spiral side, subrectangular on umbilical side. Sutures, curved, limbate, beaded, elevated on spiral side, depressed, curved to nearly straight and radial on umbilical side. Wall calcareous, perforate, radial in structure, surface of initial chambers rugose on spiral side, lightly rugose to smooth on umbilical side. Umbilicus wide and deep. Aperture interiomarginal, umbilical, tegilla with intra- and infralaminal accessory apertures.

Greatest diameter of hypotypes 0.58-0.73 mm, thickness 0.27-0.31 mm.

Remarks: Globotruncana coronata Bolli is readily distinguished from the allied *G. linneiana* (d'Orbigny) and *G. tricarinata* (Quereau) by the large size, low biconvex test, narrow double keels, and wide umbilicus.

Types and occurrences: Figured hypotypes from the Funks Formation, Funks Creek, Colusa Co. (UCLA loc. 5229); Rosario Formation, San Diego Co.; Sites Formation, Yolo Co.

Unfigured hypotypes from Yolo Formation, Salt Creek, Colusa Co., and Sites Formation, Cache Creek, Yolo Co. (UCLA loc. 5238, and 5232, respectively).

This species is common in Europe (Bolli, 1945; Klaus, 1959; Van Hinte, 1963), North Africa (Dalbiez, 1955), Soviet Union (Subbotina, 1953), and Trinidad, West Indies (Bolli, 1957).

The stratigraphic range appears to be Upper Turonian to Santonian, possibly extending into the Campanian.

GLOBOTRUNCANA CRETACEA (d'Orbigny)

Pl. 1, figs. 7, 8

Globigerina cretacea D'ORBIGNY, 1840, Soc. Geol. France, Mém., Paris, Tome 4, No. 1, p. 34, pl. 3, fig. 12-14.

Globigerina cretacea d'Orbigny, BANNER AND BLOW, 1960, Cushman Found. Foram. Res., Cont., v. 11, pt. 1, p. 8, pl. 7, fig. 1. (LECTOTYPE)

Test free, low trochospiral, biconvex, axial periphery ovate, with two weak keels commonly present on all but ultimate chamber, all chambers with poreless margin, equatorial periphery moderately lobate. Chambers 5 or 6 in final whorl, increasing gradually in size, globular, inflated, becoming elongate in direction of coiling, final chamber commonly slightly compressed. Sutures distinct, slightly curved, depressed on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface pustulose to hispid, initial chambers more coarsely ornamented, final chamber nearly smooth. Umbilicus wide, deep. Primary aperture interiomarginal, umbilical, commonly with tegilla showing intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.33-0.35 mm, thickness 0.14-0.17 mm.

Remarks: Specimens of *G. cretacea* (d'Orbigny) from the Pacific, Gulf and Atlantic Coasts agree with the lectotype described by Banner and Blow (1960). Axial sections show a well developed double keeled juvenile stage with progressive loss of the keels in later chambers. Consequently, adult forms may appear to be keel-less with a narrow poreless margin.

Types and occurrences: Figured typotypes from Point Loma, San Diego Co. (UCLA loc. 5225); Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235).

Unfigured hypotypes from Cretaceous strata, Punta Descanso, Baja California, Mexico (UCLA loc. 5226), and Marsh Creek Formation, Contra Costa Co. (UCLA loc.

5234), California; Austin Group, Travis Co., Texas (loc. 226-T-4, Plummer, 1931), Taylor Group, Dallas Co., Texas (loc. 226, Cushman, 1946); Mt. Laurel-Navesink Formation, Delaware (loc. DK-6, Olsson, 1964).

Based on examined specimens, this species appears to range from Coniacian to early Maestrichtian.

GLOBOTRUNCANA ELEVATA (Brotzen)

Pl. 3, fig. 2

Rotalia elevata BROTZEN, 1934, Deutsch. Ver. Palästinas, Zeitschr., v. 57, p. 66, pl. 3, fig. c.

Test free, low trochospiral, biconvex, spiral side slightly convex, strongly umbilicoconvex, axial periphery acute with distinct single keel, equatorial periphery moderately lobate. Chambers 6 to 7 in final whorl, increasing gradually in size, ultimate chambers often reduced in size, petaloid in spiral view, subpetaloid in umbilical view. Sutures curved, elevated, limbate, beaded on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth to slightly pustulose. Umbilicus moderately wide, deep. Primary aperture interiomarginal, umbilical, covered by tegilla with intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.68 mm, thickness 0.40 mm.

Remarks: This species is distinguished from *G. stuartiformis* Dalbiez by its more numerous petaloid chambers, more lobate equatorial periphery, distinct single keel, relatively flat spiral side and more strongly convex umbilical side.

Globotruncana elevata (Brotzen) has been recorded from the Near East (Brotzen, 1934), North Africa (Dalbiez, 1955), Europe (Knipscheer, 1956), the Gulf-Caribbean area (Pessagno, 1962, 1966, in press) and the Atlantic Coast of North America (Olsson, 1964).

Its stratigraphic range is from Campanian to Maestrichtian.

Types and occurrences: Figured hypotype from the Rosario Formation, La Jolla, San Diego Co., Calif. (UCLA loc. 5241).

Unfigured hypotypes from Point Loma, San Diego Co. (UCLA loc. 5225).

GLOBOTRUNCANA FORNICATA Plummer

Pl. 2, figs. 1-4

Globotruncana fornicata PLUMMER, 1931, Texas Univ. Bull. no. 3101, p. 198, pl. 13, figs. 4a-c, 5, 6.

Test free, low trochospiral, biconvex, moderately umbilicate, axial periphery angular truncate with two distinct keels, equatorial periphery slightly lobate. Chambers increascreasing gradually in size, 5 or 6 in final whorl, commonly somewhat inflated, elongate, crescentic on spiral side, subrectangular on umbilical side, overlapping. Sutures, curved, limbate, beaded on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface initially pustulose later chambers smooth. Umbilicus wide and deep. Aperture interiomarginal, umbilical, covered by tegilla with infra- and intralaminal apertures commonly preserved.

Greatest diameter of hypotypes 0.41-0.56 mm, thickness 0.26-0.35 mm.

Remarks: Pacific Coast representatives differ slightly from examined topotypes of *G. fornicata* Plummer. Although they retain the diagnostic spiral and umbilical features, the figured hypotypes are thicker, have coarser surface and carinal ornamentation on early chambers and are more spiroconvex. These differences are considered to represent geographic and/or ecologic variations. As the California forms are associated with the same planktonic assemblage and occupy roughly the same stratigraphic position as does the type, there appears little justification for the proposal of a new taxon based on these variations. There seems little doubt, based on external morphology, that they belong to the *G. fornicata* group. Such differences as occur appear analogous to variation in recent planktonic species from different water masses (Boltovskoy, 1959; Brinton, 1962).

The specimens referred by Takayanagi to *G. fornicata* Plummer belongs in part to *G. linneiana* (d'Orbigny).

Types and occurrences: Figured hypotypes from lower part of the Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5230) and the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241); Marsh Creek Formation, Contra Costa Co., (UCLA loc. 5235).

Unfigured hypotypes from the Upper Taylor Group, Travis Co., Texas (Plummer, 1931, loc. 226-T-8).

Unfigured hypotypes from Maestrichtian strata, Marsh Creek, Contra Costa Co. (UCLA loc. 5235). Also reported from the Panoche Formation, Contra Costa Co., California (Graham and Clark, 1961).

Unfigured hypotypes from: Austin Chalk, Dallas Co., Tex., (loc. 298, Cushman 1946), Lower Taylor Group, Dallas Co., (loc. 226, Cushman, 1946); Upper Taylor Group Travis Co. Tex., (loc. 148, Cushman, 1946), Pecan Gap Chalk, Travis Co. Tex., (loc. 226-T-7, Plummer, 1931); Mt. Laurel-Navesink Formation, Delaware, (loc. DK-6 Olsson, 1964); Marshalltown Formation, New Jersey, (loc. NJK 128, Olsson, 1964).

Recorded by Bolli (1957) from the Naparima Hill and Guayaguayare Formations, Trinidad, West Indies and from northeastern Colombia, South America, by Gandolfi (1955).

The range of this species in the western hemisphere appears to be from late Coniacian through Campanian, into early Maestrichtian. The Turonian record from the West Coast (Takayanagi, 1965) is based on a misidentification.

GLOBOTRUNCANA HAVANENSIS Voorwijk

Pl. 1, figs. 9, 10

Globotruncana havanensis VOORWIJK, 1937, Kon. Akad. Wetensch. Amsterdam Proc. v. 40, p. 195, pl. 1, fig. 25, 26, 29.

Test free, low trochospiral, biconvex to spiroconvex, axial periphery acute with a single keel that may become an imperforate band on last chamber. Chambers 5 to 6 in final whorl, increasing moderately in size, subglobular, compressed. Sutures on spiral side slightly curved, depressed, may be slightly limbate, beaded to smooth, umbilical sutures radial to slightly curved, depressed. Wall calcareous, finely perforate, radial in structure, surface finely hispid to smooth. Umbilicus small, shallow. Primary aperture interiomarginal, umbilical with apertural flaps that later may form a tegilla with intra- and infralaminal accessory apertures.

Greatest diameter of hypotypes 0.39-0.43 mm, thickness 0.12-0.14 mm.

Remarks: This species also appears to be cosmopolitan in the late Upper Cretaceous. It is represented in the Caribbean area (Voorwijk, 1937; Bolli, 1951; Ayala, 1954; Olvera, 1959; Pessagno, 1966, in press), the Pacific Coast, North Africa (Dalbiez, 1955), in Europe (Berggren, 1962; Van Hinte, 1963). Specimens from these various areas show little morphologic variation. A closely related form is *G. petaloidea* Gandolfi but the latter differs in possessing a poreless margin rather than a distinct keel, and in having more strongly inflated chambers. Both *G. havanensis* Voorwijk and *G. petaloidea* Gandolfi differ from associated globotruncanids in being more compressed, single to nonkeeled and having more fragile tests. This latter characteristic possibly reflects a difference in wall structure, in which case, they may in the future again be referred to the genus *Globotruncanella* Reiss.

The stratigraphic range extends from Late Campanian through Maestrichtian.

Types and occurrences: Figured hypotypes from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5237); Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235).

Unfigured topotypes from the Habana Formation, Cuba, collected by Max Furrer. Unfigured hypotypes from Punta Descanso, Baja California, Mexico; San Miguel Island, Santa Barbara Co., California.

GLOBOTRUNCANA IMBRICATA Mornod

Pl. 4, fig. 2

Globotruncana imbricata MORNOD, 1949, Eclogae Geol. Helv., v. 42, p. 589, fig. 5, III a-d, II a-c, IV a-c, pl. 15, figs. 21-34.

Test free, spiral side flat to slightly convex, inner whorls somewhat raised, axial periphery angular truncate, with two well developed keels, wide carinal band, equatorial periphery slightly lobate, nearly circular. Chambers subcircular on spiral side, subrectangular on umbilical side, overlapping, 5 or 6 in final whorl. Sutures depressed, gently curved backwards on spiral side, depressed and nearly radial on umbilical side. Wall calcareous, perforate, surface frequently rugose on inner whorls, last chambers smooth. Umbilicus wide and deep. Primary aperture interiomarginal, umbilical. Specimens frequently with smooth, oval shaped area surrounding primary aperture, rarely covered by bulla-like structure.

Greatest diameter of hypotype 0.34 mm, thickness 0.26 mm.

Remarks: This species is differentiated from *Globotruncana linneiana* (d'Orbigny) by its nearly circular outline, lack of a periumbilical extension of the ventral keel, and frequent lack of an umbilical keel on the last chamber. It is separated from *G. coronata* Bolli and *G. arca* (Cushman) by its consistently smaller size, nearly flat spiral and umbilical sides and smooth outline.

Occasional specimens possess small bulla-like structures over the aperture (pl. 4, fig. 2). Where these are broken, a thin rim of calcite may surround the aperture (similar to that shown on *Praeglobotruncana stephani* (Gandolfi), pl. 4, fig. 1).

Types and occurrences: Figured hypotype from the lower Sites Formation, Funks Creek, Colusa Co. (UCLA loc. 5228).

Unfigured hypotypes from the Yolo Formation, Salt Creek, Colusa Co. (UCLA loc. 5238); Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5233).

GLOBOTRUNCANA LINNEIANA (d'Orbigny)

Pl. 4, figs. 6-8; Pl. 5, figs. 4, 6, 9

Rosalina linneiana D'ORBIGNY, 1938, *in* RAMON DE LA SAGRA, Histoire physique politique et naturelle de l'Ile de Cuba, v. 8, p. 101, pl. 5, fig. 11-12.

Globotruncana linneiana (d'Orbigny). BRÖNNIMANN AND BROWN, 1956, Eclogae Geol. Helv., v. 48 (1955), p. 540, pl. XX, figs 13-15 (NEOTYPE).

Test free, low trochospiral, spiral and umbilical sides nearly flat to slightly biconvex, axial periphery angular truncate with two distinct keels, carinal band parallel to axis of coiling, equatorial periphery lobate. Chambers increasing gradually in size, 6 to 7 in final whorl, final chambers may be of somewhat reduced size, chambers petaloid on spiral side, subrectangular on umbilical sside. Sutures curved, elevated, limbate, beaded on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth to finely pustulose. Primary aperture interiomarginal, umbilical, well preserved specimens possess tegilla with infra- and intralaminal accessory apertures.

Greatest diameter of hypotypes 0.26-0.71 mm, thickness 0.14-0.24 mm.

Remarks: The taxonomic history of this common, widespread species has been discussed at length elsewhere (Brönnimann and Brown, 1956; Trujillo, 1960; Berggren, 1962). The writers consider *G. lapparenti* Brotzen to be synonymous with *G. linneiana* (d'Orbigny).

The species first appears in the Turonian as a compressed, parallel sided, double keeled form. By late Campanian, an evolutionary trend leads to a thickening of the test, resulting in a wider carinal band, and chambers that become more lobate and petalose. The recorded range is from the upper Turonian to the lower Maestrichtian.

Types and occurrences: Figured hypotypes; Venado Formation, Putah Creek, Yolo Co. (UCLA loc. 5227), Sites Formation, Funks Creek, Colusa Co. (UCLA loc. 5228), Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241), Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235).

Unfigured hypotypes, from the Austin, Taylor, and Navarro Groups (Cushman, 1946); Mt. Laurel-Navesink and Marshalltown Formations, New Jersey and Delaware (Olsson, 1964).

GLOBOTRUNCANA MARGINATA (Reuss)

Pl. 2, fig. 9

Rosalina marginata REUSS, 1845, Böhm. Kreide. 1, p. 36, pl. 8, fig. 54, 74, pl. 13, fig. 68.

Test free, low trochospiral, biconvex, axial periphery angular truncate with two keels bordering a narrow carinal band, equatorial periphery lobate. Chambers globular, subcircular on spiral side, inflated, subrectangular, on umbilical side. Sutures depressed, curved, limbate, beaded on spiral side, depressed, gently curved to nearly radial on umbilical side. Wall calcareous, perforate, radial, surface with coarse spines or hispid, carinal band smooth. Umbilicus wide and deep. Primary aperture interiomarginal, umbilical, covered by tegilla with intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.46 mm, thickness 0.24 mm.

Remarks: The narrowly spaced keels and greatly inflated chambers of this species serves to distinguish it from other double keeled globotruncanids. California specimens compare well with the lectotype figured by Cushman (1946, pl. 62, figs. 1a-c).

This species is very abundant in Niobrara strata of the Plains states but is a minor element of the fauna in the West Coast. Forms referred to *Globotruncana paraventricosa* Hofker by Graham and Church (1963) and Martin (1964) are probably identical to *G. marginata* (Reuss).

Types and occurrences: Figured hypotype from the Forbes Formation, Putah Creek, Yolo Co. (Superior Oil loc. F-119).

Unfigured specimens from the Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5231); Marsh Creek Formation, Contra Costa Co.

GLOBOTRUNCANA MARIEI Banner and Blow

Pl. 2, fig. 8; Pl. 3, fig. 8

Globotruncana mariei BANNER AND BLOW, 1960, Cushman Found. Foram. Res., Contr., v. 11, pt. 1, p. 8.

Test free, low trochospiral, biconvex, axial periphery acute to slightly truncate, initially with two keels, the umbilical keel being weaker and often lacking on later chambers, carinal band sloping strongly towards umbilicus. Chambers increase gradually in size, 5 to 6 in final whorl, broadly petaloid on spiral side, subpetaloid on umbilical side. Sutures curved, limbate, flush to slightly elevated, beaded on spiral side, radial to slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface initially beaded, later becoming smooth. Umbilicus moderately wide and deep. Primary aperture interiomarginal, umbilical, covered by tegilla, with intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.35-0.39 mm, thickness 0.18-0.22 mm.

Remarks: This species is separated from *G. arca* (Cushman) by its compressed chambers, narrow double keel tending to become single on the final chamber, and the less truncate axial periphery.

Types and occurrences: Figured hypotypes from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241); Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5231).

Unfigured hypotypes from Cretaceous strata, Punta Descanso, Baja California, Mexico; Austin, Taylor, and Navarro Groups of Texas (Cushman, 1946).

This species, originally described from the Selma Chalk of Tennessee, has also been reported from the Maestrichtian of New Jersey (Olsson, 1964) and Scandinavia (Berggren, 1962).

GLOBOTRUNCANA NOTHI Brönnimann and Brown

Pl. 2, fig. 5

Globotruncana nothi BRÖNNIMANN AND BROWN, 1965, Eclogae Geol. Helv., v. 48, no. 2, p. 551, pl. 22, figs. 16-18.

Test free, of medium to large size, low trochospiral, biconvex, axial periphery angular truncate to subacute with two distinct, closely spaced keels, equatorial periphery lobate. Chambers globular, subcircular to petaloid on spiral side, inflated, subtriangular on imbilical side, only slightly overlapping, 5 or 6 in final whorl, increasing regularly in size. Sutures curved, limbate, distinct, beaded on spiral side, depressed, nearly radial on umbilical side. Wall calcareous, perforate, radial in structure, surface coarsely rugose in central part of chambers on spiral and umbilical side, outer edges of chambers and carinal band smooth. Umbilicus wide and deep. Primary aperture interiomarginal, umbilical, tegilla with intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.63 mm, thickness 0.31 mm.

Remarks: This distinctive taxon is easily recognized by the coarse rugosities on the chamber walls and inflated, conical umbilical chambers. Specimens from California differ in the degree of ornamentation from Tethyan examples of the species. The rows of coarse spines along the keels are replaced by heavy beads and the rugosities on the spiral side are frequently restricted to the center of the chambers.

Types and occurrences: Figured hypotype from Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235).

In California this species is known only from the early Maestrichtian.

GLOBOTRUNCANA PETALOIDEA Gandolfi

Pl. 1, fig. 11

Globotruncana (Rugoglobigerina) petaloidea petaloidea GANDOLFI, 1955, Bull. Amer. Paleont., v. 36, no. 155, p. 52, pl. 3, fig. 12 a-c.

Test free, low trochospiral, low to moderately spiroconvex, slightly umbilicoconcave, axial periphery ovate to subacute, with poreless margin on all chambers. Chambers 4 or 5 in final whorl, increasing rapidly in size, subglobular, compressed. Sutures slightly curved and depressed on spiral side, radial and depressed on umbilical side. Wall calcareous, finely perforate, radial in structure, surface moderately to lightly hispid, coarser spines often located along chamber periphery. Umbilicus narrow, shallow. Aperture an interiomarginal, extraumbilical-umbilical arch with prominent apertural flap extending over portion of umbilicus.

Greatest diameter of holotype 0.24 mm, thickness 0.10 mm.

Remarks: Differences of opinion have arisen over the taxonomic position of this widespread species. Originally described as a globotruncanid by Gandolfi, later authors have placed it in the genus *Praeglobotruncana* (Berggren, 1962; Olsson, 1964). In our material this species closely resembles *G. havanensis* Voorwijk in possessing the imperforate margin but lacking the strongly compressed chambers and distinct keel. Because of its poreless margin the species cannot be included in the genus *Hedbergella.* In the Pacific Coast material, no tegilla have been observed, however, spatulate apertural flaps are present which may represent the remnants of a fragile tegillum. Because of this feature and the close resemblance to *G. havanensis,* the species is herein referred to the genus *Globotruncana* pending examination of better preserved material (see remarks under *G. havanensis* Voorwijk).

Types and occurrences: Figured hypotype from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241).

Unfigured hypotypes from: Cretaceous strata, Punta Descanso, Baja California, Mexico)UCLA loc. 5226), Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235); Navarro Group, Travis Co. Tex. (loc. 174-T-4, Plummer, 1931); Mr. Laurel-Navesink Formation, Delaware (loc. DK-6, Olsson, 1964).

The stratigraphic range appears to be late Campanian through Maestrichtian.

GLOBOTRUNCANA ROSETTA (Carsey)

Pl. 3, figs. 6, 7

Globigerina rosetta CARSEY, 1926, Texas Univ. Bull., no. 2512, p. 44, pl. 5, figs. 3 a-b.

Test free, trochospiral, biconvex, spiral side slightly convex, umbilical side moderately to strongly convex, axial periphery acute with single keel, equatorial periphery moderately lobate. Chambers 5 to 6 in final whorl, increasing gradually in size, broadly petaloid on spiral side, subpetaloid on umbilical side. Sutures curved, limbate, beaded on spiral side, nearly radial, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth. Umbilicus moderately wide, deep. Aperture interiomarginal, umbilical, covered by tegilla with infra- and intralaminal accessory apertures.

Greatest diameter of holotypes 0.36-0.46 mm; thickness 0.17-0.24 mm.

Remarks: Pessagno (1960) remarked that this was the most misidentified species of *Globotruncana.* Although this is possibly an overstatement, it is true that there are several varying concepts of *G. rosetta* (Carsey). Illustrated specimens from California (Bandy, 1951; Martin, 1964) and elsewhere (Herm, 1962; Van Hinte, 1963; Noth, 1951) are very similar but all differ somewhat from the type. Carsey's holotype (reillustrated by Plummer, 1931) and our topotypic specimens are distinctly plano-convex, with an acute peripheral section and straight sided chambers on the umbilical side. This morphologic type seems restricted to the Gulf region. Specimens from the Pacific Coast are more biconvex, with a less acute axial periphery, and somewhat curved umbilical sides of the chambers. This appears to represent the more common morphologic form, judging from the published record. We do not believe these features warrant separation of a new taxon.

A small percentage of typical *G. rosetta* (Carsey) initially have two keels. Such forms on the West Coast have only a weakly developed or incipient second keel. A double keeled form which bears some similarity is *G. mariei* Banner and Blow. However, the latter is more compressed, strongly double keeled and occasionally has flange—like ornamentation which extends from the umbilicus to the margin (pl. 3, fig. 8). A few specimens of *G. stuartiformis* Dalbiez somewhat resembles *G. rosetta* (Carsey) but are more spirally convex, have inflated umbilical chambers and stronger ornamentation and are consistently larger.

Types and occurrences: Figured hypotypes from March Creek, Contra Costa Co. (UCLA loc. 5235); and Carlsbad, San Diego Co. (UCLA loc. 2412).

Recorded from the Panoche Group, Fresno Co., California (Martin, 1964) as *Globotruncana goudkoffi* Martin.

GLOBOTRUNCANA STUARTIFORMIS Dalbiez

Pl. 3, figs. 3-5

Globotruncana (Globotruncana) elevata stuartiformis DALBIEZ, 1955, Micropaleontology, vol. 1, no. 2, p. 169, text-fig. 10.

Test free, low trochospiral, biconvex, spiral side slightly convex, umbilical side more strongly convex, axial periphery acute with prominent single keel and occasional row of pustules simulating second keel. Chambers 6 to 7 in final whorl, increasing gradually in size, broadly petaloid to subangular on spiral side, subpetaloid on umbilical side. Sutures curved, elevated, limbate and beaded on spiral side, slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth on spiral side, smooth to pustulose on umbilical side. Umbilicus moderately large and deep. Primary aperture interiomarginal, umbilical tegilla and accessory apertures rarely preserved.

Greatest diameter of hypotypes 0.44-0.59 mm, thickness 0.26-0.35 mm.

Remarks: This species was originally described from the Upper Cretaceous of Tunisia and is herein recorded from California and northwestern Mexico. It is distinguished from *G. rosetta* (Carsey) by the more umbilicoconvex test, the subangular chambers and in possessing a single keel throughout development of the test. The subangular chambers, more convex spiral side and acute axial periphery separates the species from *G. elevata* (Brotzen).

Globotruncana putahensis Takayanagi, originally described from the Campanian of northern California, represents a gradational variant of this species. It was separated from the *"elevata-stuartiformis"* group by Takayanagi (1965) because he believed it possessed two keels. Examination of numerous axial thin-sections indicates it in single keeled.

A further morphologic variation within this species is noted in the degree of surface ornamentation. Certain specimens exhibit pronounced radial flanges on the umbilical surface (pl. 3, fig. 3) or commonly show broken septa resembling flanges. As these forms show no other divergent characters they have been retained within this species.

The stratigraphic range of this species is early Campanian to late Maestrichtian.

Types and occurrences: Figured hypotypes from Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235); Point Loma, San Diego Co. (UCLA loc. 5225).

Unfigured hypotypes from Punta Descanso, Baja California, Mexico (UCLA loc. 5226); Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5241); Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5231); and Stanford University Campus (Graham and Church, 1963).

GLOBOTRUNCANA TRICARINATA
(Quereau)
Pl. 4, figs. 9, 10

Pulvinulina tricarinata QUEREAU, 1893, Beitr. Geol. Karte Schweiz, no. 33, pl. 5, fig. 3a.

Test free, low to moderate trochospiral, biconvex, axial periphery angular truncate with two distinct keels, carinal band parallel to axis of coiling, periumbilical extension of umbilical carinae elevated to form "third" keel, equatorial periphery slightly lobate. Chambers 6 to 7 in final whorl, subpetaloid on spiral side, subrectangular on umbilical side. Sutures curved, limbate, elevated, beaded on spiral side, radial to slightly curved on umbilical side. Wall calcareous, perforate, radial in structure, surface initially often pustulose, later chambers smooth. Umbilicus wide and deep. Primary aperture interiomarginal, umbilical, tegilla present in well preserved material, showing intra- and infralaminal accessory apertures.

Greatest diameter of hypotypes 0.34-0.36 mm, thickness 0.19-0.21 mm.

Remarks: This species was originally described from thin-sections (Quereau, 1893), without reference to its external morphology. For this reason, the exact concept of this species remains uncertain. Nevertheless, the original description appears to characterize a form that can be distinguished within the *"linneiana"* group. Specimens herein referred to this species are recognized by the flat spiral side, a cardinal band nearly parallel to the axis of coiling and the raised periumbilical extension of the carinae forming an apparent "third keel". By the above features, they may be separated from the lectotype of *G. linneiana*. Other species which appear to be closely related are *G. coronata* Bolli, *G. marginata* (Reuss) and in particular, *G. arca* (Cushman). *Globotruncana tricarinata* (Quereau) has in fact been suggested as the form ancestral to *G. arca* (Cushman), but the stratigraphic evidence does not appear to us to be as definitive as other writers have suggested (Berggren, 1962; Olsson, 1964). Homeomorphy has been cited as a possible explanation for the Turonian to Maestrichtian range of this species (Berggren, 1962).

Types and occurrences: Figured hypotypes from Cretaceous strata, Carlsbad, San Diego Co. (UCLA loc. 2412); Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5231).

Unfigured hypotypes from Cretaceous strata, Punta Descanso, Baja California, Mexico (UCLA loc. 5226).

GLOBOTRUNCANA VENTRICOSA White
Pl. 3, fig. 1

Globotruncana canaliculata var. *ventricosa* WHITE, 1928, Jour. Paleontology, v. 2, no. 4, p. 284, pl. 38, figs. 5a-c.

Test free, low trochospiral, slightly biconvex to planoconvex, spiral side nearly flat, umbilical side strongly convex, axial periphery angular truncate with two closely spaced keels, equatorial periphery lobate. Chambers 6 or 7 in final whorl, increasing gradually in size, petaloid on spiral side, subpetaloid on umbilical side. Sutures curved, elevated, limbate, beaded on spiral side, slightly curved, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface smooth, often initially beaded. Umbilicus wide, deep. Aperture interiomarginal, umbilical, commonly with tegilla showing intra- and infralaminal accessory apertures.

Greatest diameter of hypotype 0.54 mm; thickness 0.26 mm.

Remarks: Originally described from Mexico, this species is also reported from Europe, the Caribbean region, California, Australia and the mid-Pacific. It is distinguished by the nearly flat spiral side, the closely set double keels, and the strongly convex umbilical side.

Types and occurrences: Figured hypotype from Cretaceous strata at Point Loma, San Diego Co. (UCLA loc. 5225).

Unfigured hypotypes from Punta Descanso, Baja California, Mexico (UCLA loc. 5226); and from Marsh Creek Formation, Contra Costa Co., California.

Genus RUGOGLOBIGERINA Brönnimann, 1952

RUGOGLOBIERINA PILULA Belford

Pl. 1, figs. 3, 4

Rugoglobigerina pilula BELFORD, 1960, Bur. Mines, Res., Geol., Geophy., Bull. 57, p. 92, pl. 25, fig. 7-13, text-fig. 6 (1-6).

Test free, small, low to moderately trochospiral, biconvex, axial periphery ovate, equatorial periphery lobate. Chambers globular, inflated, subcircular on spiral side, subrectangular on umbilical side, increasing regularly in size, generally 5 in last whorl. Sutures, depressed, gently curved on spiral side, depressed and curved to nearly radial on umbilical side. Wall calcareous, perforate, radial in structure, surface finely spinose, arranged in radiating lines from marginal midpoint of each chamber. Umbilicus wide and shallow. Aperture interiomarginal, umbilical, with large bordering apertural flap.

Greatest diameter of hypotypes 0.29-0.31 mm, thickness 0.17-0.19 mm.

Remarks: A comparison of California specimens of this species with topotypes from Western Australia indicates that they are conspecific.

Representatives from the Sacramento Valley vary from low spiroconvex (pl. 1, fig. 3) to moderately high spired (pl. 1, fig. 4). They differ from *R. rugosa* (Plummer) in their globular chambers and greater spiroconvexity. Though similar to *R. rotundata* Brönnimann, *R. pilulu* Belford possesses a smaller umbilicus with a distinct rim along the aperture.

Types and occurrences: Figured hypotypes from the Forbes Formation, Rumsey Hills, Yolo Co. (UCLA loc. 5230).

Unfigured hypotypes from the Guinda Formation, Rumsey Hills, Yolo Co.

Unfigured specimens from the Toolonga Calcilutite, Murchison River area, W. Australia (MR 49).

The stratigraphic range of this species is from Santonian to lower Campanian in California and Western Australia.

RUGOGLOBIGERINA ROTUNDATA Brönnimann

Pl. 1, figs. 5, 6

Rugoglobigerina rugosa rotundata BRÖNNIMANN, 1952, Bull. Amer. Paleontology, p. 34, pl. 4, figs. 7-9, text. figs. 15, 16.

Test free, large, high to moderately trochospiral, biconvex, axial periphery ovate, equatorial periphery lobate. Chambers globular, inflated, increasing moderately in size, 5 to 7 in final whorl, only slightly produced toward the umbilicus. Sutures depressed, gently curved on the spiral side, nearly radial on umbilical side. Wall calcareous, perforate, radial in structure, surface covered by small spines and rugae, radiating from mid-point of each chamber. Umbilicus wide and deep. Aperture interiomarginal, umbilical. Broken edges of tegilla present on margins of umbilicus.

Greatest diameter of hypotypes 0.37-0.51 mm, thickness 0.26-0.34 mm.

Remarks: This species is differentiated from *Rugoglobigerina rugosa* (Plummer) by its distinct spiroconvexity and by the more numerous and globular chambers. It is possible that this distinction is artificial and that this species is merely a morphovariant of *R. rugosa* (Plummer). However, both forms are present in Trinidad where they were separated by Bronniman (1952). Until such time as intermediates are found, the two species are regarded as separate though related taxa.

Types and occurrences: Figured hypotypes from Marsh Creek Formation, Contra Costa Co. (UCLA loc. 5235).

RUGOGLOBIGERNIA RUGOSA (Plummer)

Pl. 1, fig. 2

Globigerina rugosa PLUMMER, 1926, Texas Univ. Bull., no. 2644, p. 38, pl. 2, fig. 10 a-d.

Test free, low trochospiral, biconvex, spiral side less strongly convex than umbilical side, axial periphery globular, equatorial periphery lobate. Chambers 5 or 6 in final whorl, increasing moderately in size, globular, inflated, later chambers produced towards umbilicus. Sutures slightly curved, depressed on spiral side, nearly radial, depressed on umbilical side. Wall calcareous, perforate, radial in structure, surface ornamentation rugose, radiating from a mid-chamber, peripheral point. Umbilicus wide and deep. Primary aperture interiomarginal, umbilical, covered by tegilla with intra- and infralaminal accessory apertures, rarely with apertural bulla.

Greatest diameter of hypotype 0.42 mm, thickness 0.28 mm.

Remarks: Specimens referred to this species and closely resembling the types from Texas have been recorded from New Jersey (Olsson, 1964), Mexico (Olvera, 1959), Trinidad (Brönnimann, 1952) and Europe (Berggren, 1962). Morphologic characteristics of *R. rugosa* s.s., are here considered as the nearly flat spiral side, the strongly inflated chambers, the later chambers produced toward the umbilicus, the coarse rugosities and the wide, deep umbilicus. Using these criteria, the previous California occurences (Graham and Clark, 1961; Martin, 1964, Takayanagi, 1965) are referred to other species. To date, within California *R. rugosa* (Plummer) is restricted to occurrences below 35° latitude.

Types and occurrences: Figured hypotype from the Rosario Formation, La Jolla, San Diego Co. (UCLA loc. 5237).

Unfigured hypotypes from the Corsicana Marl, Navarro Group, Travis Co., Tex. (Plummer loc. 174-T-4).

V. References

ARKELL, W. J., 1956, Jurassic Geology of the World: Oliver and Boyd Ltd., Edinburgh, 806 pp., 46 pls.

AYALA-CASTAÑARES, A., 1954, El género *Globotruncana* Cushman, 1927, y su importancia en estratigrafía: Bol. Asoc. Mex. Geol. Petr., v. 6, p. 353-438.

AYALA-CASTAÑARES, A., 1962, Morfología y estructura de algunos foraminíferos planctónicos del Cenomaniano de Cuba: Bol. Soc. Geol. Mexicana, v. 25, no. 1, p. 1-64, pls. 1-13.

BAILY, E. H., W. P. IRWIN, and D. L. JONES, 1964, Franciscan and related rocks, and their significance in the geology of western California: California Div. Mines and Geology, Bull., 183, p. 1-177, pls. 1-2, 35 text-figs., 18 tables.

BANDY, O. L., 1951, Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California: Jour. Paleontology, v. 25, no. 4, pp. 488-513, pls. 72-75.

BANDY, O. L., 1960, Planktonic foraminiferal criteria for paleoclimatic zonation: Sci. Repts., Tohoku Univ., 2nd Ser. (Geol.), spec. vol. 4, p. 1-8, 2 text-figs.

BANNER, F. T., and W. H. BLOW, 1960, Some primary types of species belonging to the Superfamily Globigerinacea: Cushman Found. Foram. Research, Contr., v. 11, pt. 1, p. 1-41, pls. 1-8.

BARR, F. T., 1962, Upper Cretaceous Foraminifera from the Isle of Wright, England: Paleontology, v. 4, p. 552-580, pls. 69-72.

BÉ, A. W. H., 1959, Ecology of Recent planktonic Foraminifera: Part 1. Areal distribution in the western Atlantic: Micropaleontology, v. 5, no. 1, p. 77-100.

BELFORD, D. J., 1960, Upper Cretaceous Foraminifera from the Toolonga Calcilutite and Gingin Chalk, Western Australia: Bur. Min. Res., Geol., Geophys., Bull. 57, p. 1-198, pls. 1-35, text-figs. 1-14.

BERGGREN, W. A., 1962, Some planktonic Foraminifera from the Maestrichtian and type Danian Stages of southern Scandinavia: Stockholm Contr. Geol., v. 9, no. 1, p. 1-106, pls. 1-14, text-figs. 1-13.

BERGQUIST, H. R., 1961, Foraminiferal zonation in Matanuska Formation, Squaw Creek-Nelchina River area, South-Central Alaska: Amer. Assoc. Petroleum Geologists, v. 45, no. 1, p. 1994-2011, 1 table.

BOLIN, E. J., 1952, Microfossils of the Niobrara Formation of southeastern South Dakota: South Dakota Geol. Survey, Rept. no. 70, p. 1-74, pls. 1-5.

BOLIN, E. J., 1956, Upper Cretaceous Foraminifera, Ostracoda and Radiolaria from Minnesota: Jour. Paleontology, v. 30, no. 2, p. 278-298, pls. 37-39, 5 text-figs.

BOLLI, H. M., 1945, Zur stratigraphie der oberen Kreide in den hoheren helvetischen Decken: Eclogae Geol. Helv., v. 37, no. 2, p. 217-328, pl. 9, text-figs. 1-6.

BOLLI, H. M., 1951, The genus *Globotruncana* in Trinidad, B. W. I.: Jour. Paleontology, v. 25, no. 2, p. 187-199, pls. 34-35.

BOLLI, H. M., 1957, The genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in the Upper Cretaceous of Trinidad, B. W. I.: U. S. Nat. Mus., Bull., no. 215, p. 51-60, pls. 12-14, text-fig. 10.

BOLTOVSKOY, E., 1959, Foraminifera as biological indicators in the study of ocean currents: Micropaleontology, v. 5, p. 473-481, pls. 1-3, text-fig. 1.

BOWEN, R., 1961a, Oxygen isotope paleotemperature measurements on Cretaceous Belemnoidea from Europe, India and Japan: Jour. Paleontology, v. 35, no. 5, p. 1077-1084, 3 text-figs.

BOWEN, R., 1961b, Paleotemperature analyses of Mesozoic Belemnoidea from Germany and Poland: Jour. Geology, v. 69, p. 75-83.

BOWEN, R. 1961c, Paleotemperature analyses of Mesozoic Belemnoidae from Australia and New Guinea: Geol. Soc. America, v. 72, p. 769-774.

BRADSHAW, J. S., 1959, Ecology of living Planktonic Foraminifera in North and equatorial Pacific Ocean: Cushman Found. Foram. Research, Contr., v. 10, pt. 2, p. 25-64, pls. 6-8, text-figs. 1-43.

BRINTON, E., 1962, The distribution of Pacific Euphausiids: Bull. Scripps Inst. Oceanogr., Univ. California, v. 8, no. 2, p. 51-270, text-figs. 1-126.

BRÖNNIMANN, P., 1952, Globigerinidae from the Upper Cretaceous (Cenomanian-Maestrichtian) of Trinidad, B. W. I.: Bull. Amer. Paleontology, v. 34, no. 140, p. 1-70, pls. 1-4, text-figs. 1-30.

BRÖNNIMANN, P., and N. K. BROWN, 1956, Taxonomy of the Globotruncanidae: Eclogae Geol. Helv., v. 48 (1955), p. 503-561, pls. 20-24, text-figs. 1-24.

BRÖNNIMANN, P., and D. RIGASSI, 1963, Contributions to the Geology and Paleontology of the area of the City of La Habana, Cuba, and its surroundings: Eclogae Geol. Helv., v. 56, no. 1, p. 193-480, pls. 1-26.

BROTZEN, F., 1934, Foraminiferen aus dem Senon Palästinas: Deutsch. Ver. Palästinas, Zeitschr., Leipzig, v. 57, p. 28-72, text-figs. 1-4.

CAMPBELL, A. S., 1954, Treatise on Invertebrate Paleontology, Part D, Protista 3, Chiefly Radiolarians and Tintinnines (ed. R. C. Moore), p. 1-195, text-figs. 1-92.

CARSEY, D. O., 1926, Foraminifera of the Cretaceous of central Texas: Texas Univ., Bull. no. 2612, p. 1-56, pls. 1-8.

CITA, M. B., 1948, Ricerche stratigrafiche e micropaleontologiche sul Cretacico e sull Eocene di Tignale (Lago di Garda): Riv. Ital. Pal., v. 54, no. 2, p. 49-74; no. 3, p. 117-133; no. 4, p. 143-168, pls. 2-4.

CLOUD, P. E. JR., 1961, Paleobiogeography of the Marine Realm; in Oceanography, edited by Mary Sears, Amer. Assoc. Adv. Sci., Pub. no. 67, p. 151-200, 12 text-figs.

COLBURN, IVAN, 1962, Geologic Guide to the Gas and Oil Fields of northern California: Field Trip #5, North flank of Mount Diablo: California Div. Mines, Geol., Bull. 181, p. 407-412, text-figs. 1-3.

CROWELL, J. C., 1962, Displacement along the San Andreas Fault, Calif.: Geol. Soc. America, Spec. Paper no. 71, p. 1-61, 1 pl., text-figs. 1-6.

CUSHMAN, J. A., 1926, Some Foraminifera from the Mendez Shale of eastern Mexico: Cushman Lab. Foram. Research, Contr., v. 2, pt. 1, p. 16-24, pls. 2-3.

CUSHMAN, J. A., 1938, Some new species of rotaliform Foraminifera from the American Cretaceous: Cushman Lab. Foram. Research, Contr., v. 14, pt. 3, p. 66-71, pls. 11-12.

CUSHMAN, J. A., 1946, Upper Cretaceous Foraminifera of the Gulf Coast Region of the United States and adjacent areas: U. S. Geol. Survey, Prof. Paper, no. 206, p. 1-241, pls. 1-66.

CUSHMAN, J. A. and C. C. CHURCH, 1929, Some Upper Cretaceous Foraminifera from near Coalinga, Colifornia: California Acad. Sci., Proc., 4th Ser., v. 18, no. 16, p. 497-530, pls. 36-41.

CUSHMAN, J. A., and H. H. RENZ, 1947, Further notes on the Cretaceous Foraminifera of Trinidad: Cushman Lab. Foram. Research, Contr., v. 23, pt. 2, p. 31-50, pls. 11-12.

DALBIEZ, F., 1955, The genus *Globotruncana* in Tunisia: Micropaleontology, v. 1, no. 2, p. 161-171, text-figs. 1-10.

ECKMAN, S., 1953, Zoogeography of the Sea: Sidgwick and Jackson Ltd., London, 417 pp.

EDGELL, H. S., 1957, The genus *Globotruncana* in northwest Australia: Micropaleontology, v. 3, no. 2, p. 101-122, pls. 1-4, text-figs. 1-4.

EICHER, D. L., 1965, Foraminifera and biostratography of the Graneros Shale: Jour. Paleontology, v. 39, no. 5, p. 875-909, pls. 103-106, 6 text-figs.

EICHER, D. L., 1966, Foraminifera from the Cretaceous Carlisle Shale of Colorado: Cushman Found. Foram. es., Contr., v. 17, pt. 1, p. 16-31, pls. 1-6, 2 text-figs.

EMILIANI, C., 1961, The Temperature decrease of surface sea-water in high latitudes and of abyssal-hadal water in open oceanic basins during the past 75 million years: Deep-sea Research, v. 8, p. 144-147.

ERICSON, D. B., M. EWING, G. WOLLIN, and B. C. HEEZEN, 1961, Atlantic deep-sea sediment cores: Geol. Soc. America, Bull. v. 72, p. 193-286.

FAGER, E. W., and J. A. MCGOWAN, 1963, Zoöplankton Species Groups in the North Pacific: Science, v. 140, no. 3566, p. 453-460, text-figs. 1-5.

FISCHER, A. G., 1960, Latitudinal variation in organic diversity: Evolution, v. 14, no. 1, p. 64-81.

FISHER, S. P. and E. A. PESSAGNO, JR., 1965, Upper Cretaceous strata of northwestern Panamá: Amer. Assoc. Petroleum Geol., Bull., v. 49, no. 4, p. 433-444, text-figs. 1-4.

FOX, S. K. JR., 1954, Cretaceous Foraminifera from the Greenhorn, Carlisle and Cody formations, South Dakota, Wyoming: U. S. Geol. Survey Prof. Paper 254-E, p. 97-124, pls. 24-26.

GANDOLFI, R., 1942, Ricerche micropaleontologische e stratigrafiche sulla Scaglia e sul Flysch Cretacici dei dintorni di Balerna (Canton Ticino): Riv. Ital. Pal., v. 48, mem. 4, p. 1-160, pls. 1-14, text-figs. 1-49.

GANDOLFI, R., 1955, The genus *Globotruncana* in northeastern Colombia: Bull. Amer. Paleontology, v. 36, no. 155, p. 1-118, pls. 1-10, text-figs. 1-12.

GANDOLFI, R., 1957, Notes on some species of *Globotruncana*: Cushman Found. Foram. Research, Contr., v. 8, p. 59-65.

GOUDKOFF, P. P., 1945, Stratigraphic relations of Upper Cretaceous in Great Valley, California: Amer. Assoc. Petroleum

Geol., Bull., v. 29, no. 7, p. 956-1007, text-figs. 1-17.

GRAHAM, J. J. and C. C. CHURCH, 1963, Campanian Foraminifera from the Stanford University Campus: Stanford Univ. Publ., Geol. Sci., v. 8, no. 1, p. 1-107, pls. 1-8, text-figs. 1-2.

GRAHAM, J. J. and D. K. CLARK, 1961, New evidence for the age of the "G-1 zone" in the Upper Cretaceous of California: Cushman Found. Foram. Research, Contr., v. 12, pt. 3, p. 107-114, pl. 5, text-figs. 1-2.

HAGN, H. and W. ZEIL, 1954, *Globotruncana* aus dem Ober-Cenoman und Unter-Turon der Bayerischen Alpen: Eclogae Geol. Helv., v. 47, no. 1, p. 1-60, pls. 1-7.

HAMILTON, E. L., 1953, Upper Cretaceous, Tertiary, and Recent planktonic Foraminifera from Mid-Pacific flattopped seamounts: Jour. Paleontology, v. 27, no. 2, p. 204-237, pls. 29-32, text-figs. 1-5.

HAMILTON, E. L., 1956, Sunken islands of the mid-Pacific mountains: Geol. Soc. America, Mem. 64, p. 1-97, figs. 1-12.

HAY, W. W., 1960, The Cretaceous-Tertiary boundary in the Tampico Embayment, Mexico: Internat. Geol. Congr. 21st, pt. 5, p. 70-77.

HERM, D., 1962, Stratigraphische und mikropaläontologische Untersucnungen der Oberkreide im Lattengebirge und Nierental: Bayer. Akad. Wiss., math.—naturw. Kl., Abh., N. F., Heft. 104, p. 1-119, text-figs. 1-9.

HILL, M. L., and T. W. DIBBLEE, JR., 1953, San Andreas, Garlock and Big Pine faults, California: Geol. Soc. America, Bull. v. 64, p. 443-458.

JENKINS, D. G., 1965, Planktonic Foraminifera and Tertiary intercontinental correlations: Micropaleontology, v. 11, no. 3, p. 265-277, pls. 1-2.

JENNINGS, P. H., 1936, A microfauna from Monmouth and basal Rancocas groups of New Jersey: Bull. Amer. Paleontology, v. 23, no. 78, p. 3-76, pls. 1-7.

JONES, D. L., 1963, Upper Cretaceous (Campanian and Maestrichtian) Ammonites from southern Alaska: U. S. Geol. Survey Prof. Paper 432, p. 1-57, pls. 1-41, 25 text-figs., 2 tables.

KLAUS, J., 1960, Le "Complexe schisteux intermédiaire" dans le synclinal de la Gruyère (Préalpes médianes): Stratigraphie et micropaléontologie, avec l'étude spéciale des Globotruncanidés de l'Albien, du Cénomanien et du Turonien: Eclogae Geol. Helv., v. 52 (1959), no. 2, p. 753-851, pls. 1-8, text-figs. 1-9.

KNIPSCHEER, H. C. G., 1956, Biostratigraphie in der Oberkreide mit Hilfe der Globotruncanen: Pälaont. Zeit., v. 30, Sonderheft, p. 50-56, pl. 4, text-figs. 1-4.

LIPPS, J. H., 1966, Wall Structure and classification of planktonic foraminifera: Geol. Soc. America, Spec. Paper, *in press*.

LOEBLICH, A. R., JR., 1958, Danian stage of Paleocene in California: Amer. Assoc. Petroleum Geol., Bull., v. 42, no. 9, p. 2260-2261.

LOEBLICH, A. R., JR., and HELEN TAPPAN, 1961, Cretaceous planktonic Foraminifera: Part 1, Cenomanian: Micropaleontology, v. 7, no. 3, p. 257-304, pls. 1-8.

LOEBLICH, A. R., JR., and HELEN TAPPAN, 1964, Treatise on Invertebrate Paleontology, Part C, Protistia 2, Chiefly Thecamoebians and Foraminiferida (ed. R. C. Moore), 2 vols., p. 1-900, figs. 1-653.

LOETTERLE, G. J., 1937, The micropaleontology of the Niobrara Formation in Kansas, Nebraska and South Dakota: Nebraska Geol. Survey, Bull., ser. 2, no. 12, p. 9-73, pls. 1-11, text-figs. 1-2.

LOWENSTAM, H. A., and S. EPSTEIN, Paleotemperatures of the post-Aptian Cretaceous as determined by the oxygen isotope method: Jour. Geology, v. 62, p. 207-248.

MARIANOS, A. W., and R. P. ZINGULA, 1966, Cretaceous Planktonic Foraminifera from Dry Creek, Tehama County, California: Jour. Paleontology, v. 40, no. 2, p. 328-342, pls. 37-39, text-figs. 1-3.

MARTIN, L., 1964, Upper Cretaceous and Lower Tertiary Foraminifera from Fresno County, California: Jb. Geol. Bundesanst., Sonderbd. 9, p. 1-128, pls. 1-16, text figs. A-D, figs. 1-5.

MATSUMOTO, T., 1960, Upper Cretaceous ammonites of California: Part III: Kyushu Univ., Fac. Sci., Mem., ser. D, Geol. Spec. v. 2, p. 1-204, pls. 1-2, text-figs. 1-20.

MCGUGAN, A., 1964, Upper Cretaceous zone Foraminifera, Vancouver Island, British Columbia, Canada: Jour. Paleontology, v. 38, no. 5, p. 933-951, pls. 150-152, text-figs. 1-4.

MORNOD, L., 1950, Les Globorotalidés du Cretacé supédieur du Montsalvens (Préalpes fribourgeoises): Eclogae Geol. Helv. v. 42, (1949), no. 2, p. 573-596, pl. 15, text-figs. 1-14.

MORROW, A. L., 1934, Foraminifera and Ostracoda from the Upper Cretaceous of Kansas: Jour. Paleontology, v. 8, no. 2, p. 186-205, pls. 29-31.

MURRAY, G., 1961, Geology of the Atlantic and Gulf Coastal Province of North America: Harper and Bros., New York, p. 1-692.

MURRAY, J., 1897, On the Distribution of Pelagic Foraminifera at the Surface and on the Floor of the Ocean: Natural Science, v. 11, no. 65, p. 17-27, text-figs. 1-5.

NAUSS, A. W., 1947, Cretaceous microfossils of the Vermilion area, Alberta: Jour. Paleontology, v. 21, no. 4, p. 329-343, pls. 48-49, 3 text-figs., 1 table.

NOTH, R., 1951, Foraminiferen aus Unter- und Oberkreide des Österreichischen Anteils an Flysch, Helvetikum und Vorlandvorkommen: Jb. Geol. Bundesanst., Sonderbd, 3, p. 1-91, pls. 1-9.

OLSSON, R. K., 1964, Late Cretaceous planktonic Foraminifera from New Jersey and Delaware: Micropaleontology, v. 10, no. 2, p. 157-188, pls. 1-7, text-figs. 1-3.

OLVERA, Y. E., 1959, Foraminiferos del Cretacico Superior de la Cuenca de Tampico-Tuxpan, Mexico: Bol. Asoc. Mex. Geol. Petr., v. 11, no. 3, 4, p. 63-134, pls. 1-9.

D'ORBIGNY, A. D., 1839, Foraminifères, *in* RAMON DE LA SAGRA, Histoire physique, politique et naturelle de L'île de Cuba: xlviii + 224 p., atlas, pls. 1-12.

D'ORBIGNY, 1840, Mémoire sur les foraminifères de la craie blanche du bassin de Paris: Soc. Geol. France, mém., v. 4, pt. 1, p. 1-51, pls. 1-4.

PALMER, R. H., 1928, The rudistids of southern Mexico: California Acad. Sci., Occasion. Papers, v. 14, p. 5-137, pls. 1-18.

PARKER, F. L., 1960, Living planktonic Foraminifera from the equatorial and southeastern Pacific: Tohoku Univ., Sci. Repts., 2nd ser. (Geol.), spec. v. 4, p. 71-82.

PARKER, F. L., 1965, Irregular distributions of planktonic Foraminifera and stratigraphic correlation: Progress in Oceangr., v. 3, p. 267-272, (Pergamon Press).

PESSAGNO, E. A., 1960, Stratigraphy and micropaleontology of the Cretaceous and lower Tertiary of Puerto Rico: Micropaleontology, v. 6, no. 1, p. 87-110, pls. 1-5, text-figs. 1-2.

PESSAGNO, E. A., 1962, The Upper Cretaceous stratigraphy and micropaleontology of south-central Puerto Rico: Micropaleontology, v. 8, no. 3, p. 348-368, pls. 1-6.

PESSAGNO, E. A., 1966, Upper Cretaceous planktonic Foraminifera from the western Gulf Coastal Plain: Paleontogr. Americana, in press.

PHLEGER, F. B, 1960, Ecology and distribution of Recent Foraminifera: John Hopkins Press, Baltimore, Maryland.

PHLEGER, F. B, F. L. PARKER, and J. F. PIERSON, 1953, North Atlantic Foraminifera: Swedish Deepsea Exped., Repts., v. 7, fasc. 1, p. 3-122, pls. 1-12.

PLUMMER, H. J., 1926, Foraminifera of the Midway Formation in Texas: Texas Univ., Bull., no. 2644, p. 1-206, pls. 1-15.

PLUMMER, H. J., 1931, Some Cretaceous Foraminifera in Texas: Texas Univ., Bull., no. 3101, p. 109-203, pls. 8-15.

POPENOE, W. P., *et al.*, 1960, Correlation of the Cretaceous Formations of the Pacific Coast (United States and Northwestern Mexico): Geol. Soc. America, Bull., v. 71, p. 1491-1540, pl. 1, text-figs. 1-5.

QUEREAU, E. C., 1893, Die Klippenregion von Iberg (Sihlthal): Beitr. Geol. Karte Schweiz (Schweiz Geol. Komm.), no. 33, p. 3-153, pl. 5.

RENZ, O., 1936, Stratigraphische und mikropaleontogische Untersuchung der Scaglia (Obere Kreide-Tertiär) um zentralen Apennin: Eclogae Geol. Helv., v. 29, no. 1, p. 1-149, pls. 1-15.

REUSS, A. E., 1845, Die Versteinerungen der Böhmischen Kreideformation: Stuttgart, E. Schweizerbarth, Abt. 1, p. 1-58, pls. 1-13.

SHAW, A. B., 1953, Preliminary survey of the Foraminifera of the lower shale of the Niobrara Formation in the Laramie Basin: Wyoming Geol. Assoc., Guidebook, 8th Ann. Field Confer., p. 47-55, pls. 1-2, 3 tables.

SIGAL, J., 1952, Aperçu stratigraphique sur la micropaléontologie du Crétacé: Congr. Géol. Internat., 19th Monogr. Rég., sér. 1, Algérie, no. 26, text-figs. 1-46.

SOHL, N. F., 1964, Neogastropoda, Opisthobranchia and Basommatrophora from the Ripley, Owl Creek, and Prairie Bluff formations: U. S. Geol. Survey, Prof. Paper, no. 331-B, p. 153-344, pls. 19-52, text-figs. 12-18.

STEPHENSON, L. W., *et al.*, 1942, Correlations of the outcropping Cretaceous formations of the Atlantic and Gulf Coastal plain and Trans-pecos Texas: Geol. Soc. America, Bull., v. 53, pp. 435-448, 1 pl.

SUBBOTINA, N. N., 1953, [Globigerinidae, Hantkeninidae and Globorotaliidae: Fossil foraminifera from the U. S. S. R.]: VNIGRI, Trudy, new ser. no. 76, p. 1-296, pls. 1-41.

TAKAYANAGI, Y., 1965, Upper Cretaceous Planktonic Foraminifera from the Putah Creek Subsurface Section along the Yolo-Solano County line, California: Tohoku Univ., Sci. Rept., 2nd ser. (Geol), v. 36, no. 2, p. 161-237, pls. 20-29, text-figs. 1-9.

TAPPAN, HELEN, 1962, Foraminifera from the Arctic Slope of Alaska Part 3, Cretaceous Foraminifera: U. S. Geol. Survey, Prof. Paper 236-C, p. 91-205, pls. 29-58, text-figs. 10-18.

THALMANN, HANS, 1942, The Genus *Globotruncana* and its species: Amer. Assoc. Petroleum Geol., 27th Ann. Convention Program, Denver, April 1942, p. 51, 52.

TRUJILLO, E. F., 1960, Upper Cretaceous Foraminifera from near Redding, Shasta County, California: Jour. Paleontology, v. 34, p. 290-346, pls. 43-50, text-figs. 1-3.

UHLIG, V., 1911, Die marinen Reiche des Jura- und der Unterkreide: Mitt. Geol. Ges., Wien, v. 4, no. 3, p. 329-448.

VAN HINTE, J. E., 1963, Zur stratigraphie und mikropaläontologie der Oberkreide und des Eozäns des Krappfeldes (Körnten): Jb. Geol. Bundesanst. Sonderbd. 8, p. 1-147, pls. 1-12, text-figs. 1-15.

VAN HINTE, J. E., 1965, The type Campanian and its planktonic foraminifera: Kon. Akad. Wetensch. Amsterdam, Proc., ser. B, v. 68, no. 1, p. 8-28, pls. 1-3, 9 text-figs.

VOORWIJK, G. H., 1937, Foraminifera from the Upper Cretaceous of Habana, Cuba: Kon. Akad. Wetensch. Amsterdam, Proc., v. 30, no. 2, p. 190-198, pls. 1-3.

WALL, J. H. and R. K. GERMUNDSON, 1963, Microfaunas, Megafaunas and Rock-stratigraphic units in the Alberta Group (Cretaceous) of the Rocky Mountain Foothills: Canadian Petrol. Geology, Bull., v. 11, no. 4, p. 327-349, 4 text-figs.

WHITE, M. P., 1928, Some index Foraminifera of the Tampico embayment area of Mexico: Jour. Paleontology, v. 2, no. 4, p. 280-317, pls. 38-42.

PLATE 1

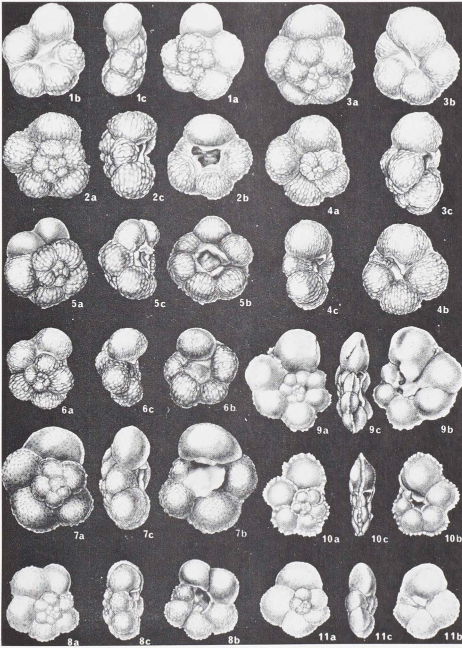

1b
1c
1a
3a
3b
2a
2c
2b
4a
3c
5a
5c
5b
4c
4b
6a
6c
6b
9a
9c
9b
7a
7c
7b
10a
10c
10b
8a
8c
8b
11a
11c
11b

PLATE 1

PLATE 2

Figures		Page
1-4.	*Globotruncana fornicata* Plummer 1 a-c, 2 a-c, hypotypes from Rosario Formation, La Jolla, San Diego County, both x 67 3 a-c, hypotype from Forbes Formation, Rumsey Hills, Yolo County, x 49 4 a-c, hypotype from Marsh Creek Formation, Contra Costa County, x 67	110
5.	*Globotruncana nothi* Brönnimann & Brown 5 a-c, hypotype from Marsh Creek Formation, Contra Costa County, x 49	113
6, 7.	*Globotruncana arca* (Cushman) 6 a-c, hypotype from Marsh Creek Formation, Contra Costa County, x 73 7 a-c, hypotype from Rosario Formation, La Jolla, San Diego County, x 67	107
8.	*Globotruncana mariei* Banner and Blow 8 a-c, hypotype from Rosario Formation, La Jolla, San Diego County, x 73	112
9.	*Globotruncana marginata* (Reuss) 9 a-c, hypotype from Forbes Formation, Rumsey Hills, Yolo County, x 67	112
10.	*Globotruncana churchi* Martin 10 a-c, hypotype from Cretaceous strata, Carlsbad, San Diego County, x 73	108

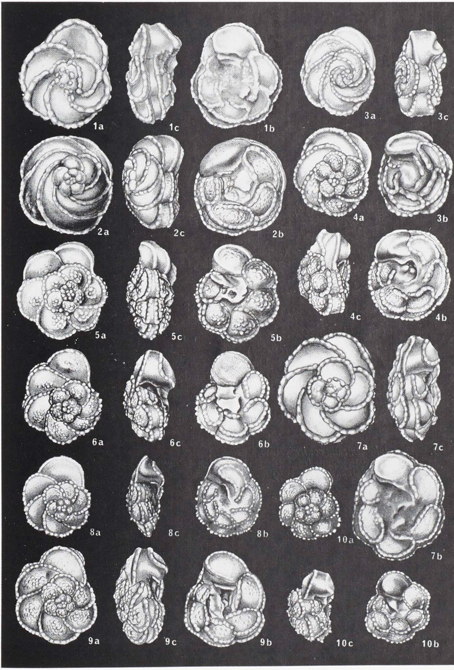

1a
1c
1b
3a
3c
2a
2c
2b
4a
3b
5a
5c
5b
4c
4b
6a
6c
6b
7a
7c
8a
8c
8b
10a
7b
9a
9c
9b
10c
10b

PLATE 2

PLATE 3

Figures		Page
1.	*Globotruncana ventricosa* White 1 a-c, hypotype from Cretaceous strata at Point Loma, San Diego County, x 67	115
2.	*Globotruncana elevata* (Brotzen) 2 a-c, hypotype from Rosario Formation, La Jolla, San Diego County, x 49	110
3, 4, 5.	*Globotruncana stuartiformis* Dalbiez 3 a-c, broken hypotype from Point Loma, San Diego County, x 67 4 a-c, 5 a-c, hypotypes from Marsh Creek Formation, Contra Costa County, both x 49	114
6, 7.	*Globotruncana rosetta* (Carsey) 6 a-c, hypotype from Carlsbad, San Diego County, x 49 7 a-c, hypotype from Marsh Creek Formation, Contra Costa County, x 73	114
8.	*Globotruncana mariei* Banner and Blow 8 a-c, hypotype from Forbes Formation, Rumsey Hills, Yolo County, x 73	112
9.	*Globotruncana conica* White 9 a-c, hypotype from Rosario Formation, La Jolla, San Diego County, x 49	108

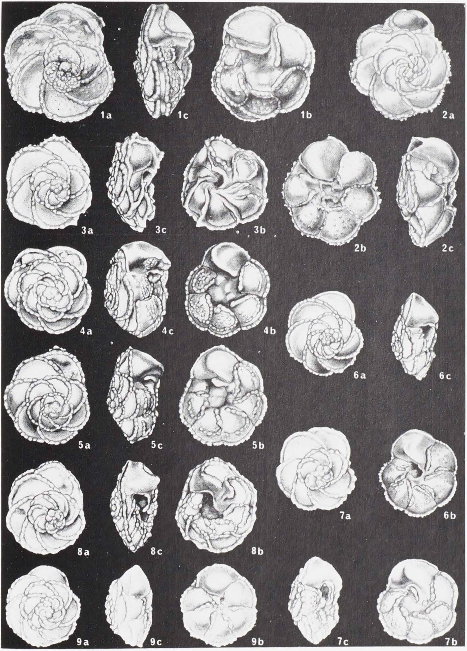

1a
1c
1b
2a
3a
3c
3b
2b
2c
4a
4c
4b
6a
6c
5a
5c
5b
7a
6b
8a
8c
8b
9a
9c
9b
7c
7b

PLATE 3

Plate 4

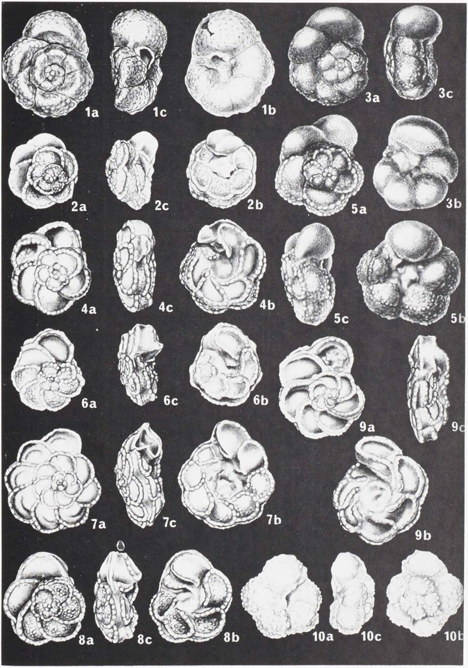

1a
1c
1b
3a
3c
2a
2c
2b
5a
3b
4a
4c
4b
5c
5b
6a
6c
6b
9a
9c
7a
7c
7b
9b
8a
8c
8b
10a
10c
10b

PLATE 4

Plate 5

Figures		Page
1.	*Praeglobotruncana helvetica* (Bolli) 1 a-c, hypotype from Venado Formation, Putah Creek, Yolo County, x 96	105
2.	*Globotruncana churchi* Martin 2 a-c, hypotype from Sites Formation, Funks Creek, Colusa County, x 67	108
3.	*Hedbergella praehelvetica* (Trujillo) 3 a-c, hypotype from Venado Formation, Putah Creek, Yolo County, x 73	104
4, 6, 9.	*Globotruncana linneiana* (d'Orbigny) 4 a-c, hypotype from Venado Formation, Putah Creek, Yolo County, x 67 6 a-c, hypotype from Sites Formation, Funks Creek, Colusa County, x 73 9 a-c, hypotype from Sites Formation, Funks Creek, Colusa County, x 49	112
5.	*Globotruncana cachensis*, n. sp. Douglas 5 a-c, holotype from Yolo Formation, Salt Creek, Colusa County, x 73	108
7, 8.	*Globotruncana coronata* Bolli 7 a-c, hypotype from Funks Formation, Funks Creek, Colusa County, x 49 8 a-c, juvenile hypotype from Sites Formation, Cache Creek, Yolo County, x 67	109
10.	*Hedbergella* sp. 1 10 a-c, figured specimen from Sites Formation, Funks Creek, Colusa County, x 73	105

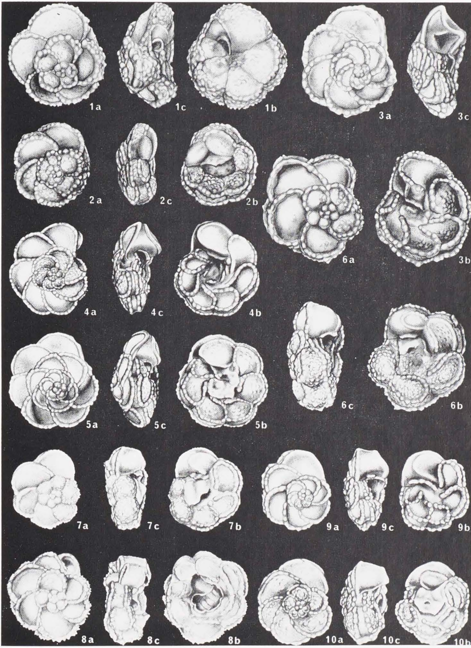

1a
1c
1b
3a
3c
2a
2c
2b
6a
3b
4a
4c
4b
6c
6b
5a
5c
5b
7a
7c
7b
9a
9c
9b
8a
8c
8b
10a
10c

PLATE 5